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INTRODUCTORY

ANALYTICAL CHEMISTRY is that branch of the science which deals with the examinations of a compound (or mixture), made with a view to the disclosure of its composition. The constituents of the compound may be merely recognized, or by some process such as weighing for example, be quantitatively determined, and thus the proportions, as well as the mere presence of the constituents be made known. Accordingly, analytical chemistry is divided into two branches—qualitative and quantitative. Qualitative analysis answers the question, "Of what constituents does the material in question consist?" Quantitative analysis answers the question, "In what amounts or proportions are these constituents present?"

In qualitative analysis, in order to detect the presence of an element, we separate it out in the free state from the compound in which it exists; or, this being impracticable, we combine it with one or more other elements to form a characteristic, easily recognized compound. The operations of quantitative analysis are very similar except for the fact that measures are taken to determine the *amounts* of the constituents present. The methods employed in quantitative analysis may be divided into three classes:

1. *Gravimetric Methods*,—in which the substance is determined by weighing. If the substance does not admit of isolation (as is frequently the case), it is converted into a new compound of definite and known composition, this being separated, weighed, and taken as a basis for the calculation of the original substance.

2. *Volumetric Methods*,—in which the amount of substance is calculated from the volume of reagent required to just complete a characteristic reaction.

3. *Gasometric Methods*,- these including all such in which a gas is evolved and measured.

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PRELIMINARY NOTES.

RULES FOR WEIGHING AND FOR CARE OF ANALYTICAL BALANCE.

1. The balance should rest on a perfect level, and should be adjusted so that the right and left arms exactly counterpoise.

2. A small wide-mouthed bottle, half filled with concentrated sulphuric acid (or recently ignited potassium carbonate) should be placed in the balance case, for the purpose of keeping the air in the case practically free from moisture.

3. Substances or vessels should never be weighed while hot. And to prevent the deposition of moisture on them, they should be cooled in dried air,—*i. e.*, in a desiccator over sulphuric acid or calcium chloride.

4. Volatile substances, as well as very hygroscopic substances, should be weighed in closed containers. The method of weighing by difference should be employed. This consists simply in weighing a quantity of the substance in the container, removing a convenient quantity for analysis, and again weighing the container with the remainder of the substance. The difference between the two readings is the amount of substance taken.

5. The substance to be weighed should never be placed upon the bare balance pan; weighing glasses should always be used.

6. The substance to be weighed should always be placed upon the left balance pan, and the weights upon the right.

7. In transferring the container with the substance from the desiccator to the balance, forceps should be used, and not the fingers. Neither should weights ever be handled with the fingers.

8. The swinging of the balance beam should always be arrested before placing weights, or articles to be weighed, upon the balance pans, and before removing the same from the balance pans.

9. In weighing, the weights should be tried systematically, beginning with the large ones and working downward.

10. The doors of the balance case should not be allowed to remain open longer than necessary. The case must be closed when the final adjustment is made with the rider. When the pointer swings to an equal distance on either side of the central line (or zero-point), the balance is in equilibrium.

11. In reading weights, but two units should be used,—grammes and milligrammes.

PRELIMINARY EXERCISES.

1. ADJUSTING THE BALANCE.

Level the balance, and adjust the same to equilibrium.

If the balance be nearly, but not quite in equilibrium, it may be used without adjustment by determining its "zero-point" as follows: - Set the beam to swinging by gently blowing upon one of the pans, and count the number of divisions on the scale through which the pointer swings, on both the right and on the left side of the central line. Allow it to vibrate thus back and forth several times, counting the number of divisions each time, and finally add up all those on the right, and all those on the left, and take the averages. Subtract the smaller from the larger average and divide the difference by two. The result gives the number of divisions from the central line, on the side on which the pointer swung farthest, at which the pointer would eventually come to rest, and which may be considered the "zero point" of the balance.

2. WEIGHING A WEIGHING-GLASS.

Subject a weighing-glass to a careful washing, drying it with a cloth which does not give off lint. Transfer the glass to an air-bath and subject it to a temperature of 105° C. for 10 minutes. Cool in a desiccator and weigh. Repeat the operations and the weighings until the last two weighings practically agree. Record the weight of the weighing-glass in a note-book for future reference.

3. WEIGHING A CRUCIBLE.

By means of a pipe-clay triangle resting on a tripod, support over a Bunsen flame, a clean porcelain crucible and lid, and heat to a dull redness for five minutes. Remove the flame, and allow the crucible and lid to cool a little; then, while still hot, transfer to a desiccator, and when quite cold, weigh. Repeat the operations and the weighings until a constant weight is obtained. Then record the weight for future use.

4. DETERMINING ASH IN FILTER-PAPER.

Place the tared crucible upon a triangle supported by a tripod, and by means of a Bunsen flame, heat to redness. Take 5 filters, selected from various parts of the package; roll each up separately into a ball; and drop them, one by one, into the red-hot crucible, — dropping the second when the first has ceased to burn, the third when the second has been reduced to a black mass, etc. When all five have been charred, slightly tilt the crucible and arrange the lid in such a manner as to prevent the loss of ashes by draught, at the same time allowing free access of air. Then continue heating until all carbon has been burnt off, and the resulting ash is perfectly white. Cool in a desiccator and weigh. The weight of ash in the crucible, divided by five, represents the weight of ash in one filter. Record this weight for future reference.

5. DETERMINING MOISTURE.

(*a*). *Substances not affected by high heat.*—Place a convenient quantity of the substance (about 2 Gm.) in a tared crucible, and weigh accurately. Heat over a Bunsen flame for from 10 to 30 minutes, cool in a desiccator, and weigh. Again heat for 10 minutes, cool, and weigh. If the two weighings do not agree, repeat the operation. When the last two weighings agree, all moisture will have been expelled.

Calculation.—From weight of substance taken, subtract weight after heating. Then, weight of substance taken : loss on heating :: 100 : x. x = % of moisture.

(*b*). *Substances decomposed by high heat, or losing other constituents besides moisture.*—Weigh out a convenient quantity in a tared beaker, cover with a filter paper, place in an air-bath, and keep at a temperature of 105° C. [120° C. in some cases] for 30 minutes. Cool in a desiccator and weigh. Again heat for 15 minutes, cool, and weigh. Repeat until the last two weighings agree. Calculation is the same as under (a).

(*c*). *Substances which undergo alteration or lose water of crystallization at a moderate heat.*—Reduce the substance to a fine powder, weigh out a convenient quantity (about 3 Gm.) on a weighing glass, transfer to a desiccator, and allow it to remain there for two hours. Weigh. Again transfer to the desiccator and keep it there for one hour. Weigh. Repeat until the last two weighings agree. Calculate in the usual way.

(*d*). *Substances which lose water of crystallization or of constitution in dry air at ordinary temperature (efflorescent salts, etc.).*—Reduce substances of this nature to a fine powder, weigh, and then press between sheets of clean filter-paper. Repeat the process several times with fresh paper, until constant weight is obtained.

6. DETERMINING WATER OF CRYSTALLIZATION.

Reduce the crystals to a fine powder, weigh out a convenient quantity (about 2 Gm.) in a perfectly dry, tared, glass stoppered weighing bottle, transfer the stopper to the desiccator and the bottle and contents to the air-bath, and heat at a temperature of 105° C. for at least 2 hours. Then transfer to the desiccator, cool, insert stopper, and weigh. Continue repeating the operation, heating each time for 30 minutes, until the weight remains constant. Calculate in the usual way.

Note.—Some substances, as for example copper sulphate and ferrous sulphate do not lose all their combined water at 105°C., and must be heated to a higher temperature.

GRAVIMETRIC DETERMINATIONS.

1. DETERMINATION OF LEAD AS LEAD SULPHATE.

Principle.—Lead is precipitated out from solutions of its salts by sulphuric acid, as lead sulphate. From the weight of the lead sulphate yielded, the amount of lead in the "unknown" is found by calculation.

Process.—Take a convenient quantity (about 1 Gm.) of the "unknown" ($Pb\,CO_3$ etc.), weigh accurately, and transfer to a number 2 beaker. Pour 20 cc. of water upon the "unknown;" then add strong nitric acid, drop by drop, until effervescence ceases; and boil for a few minutes. A clear solution should result.

$$(PbCO_3)_2\ Pb(OH)_2 \times 6HNO_3 = 3Pb(NO_3)_2 + 2CO_2 + 4H_2O.$$

Then add 25 per cent. sulphuric acid in excess, *i. e.*, until no further precipitation occurs.

$$Pb\,(NO_3)_2 + H_2SO_4 = PbSO_4 + 2HNO_3.$$

Add 20 cc. of alcohol and boil for a few minutes. As lead sulphate is more nearly insoluble in alcohol than in water, the addition of the former causes a more nearly complete precipitation. Cool, and when perfectly cold, filter through paper. Great care should be exercised in transferring the precipitate to the filter, lest some be lost in the operation, or left behind in the beaker. It is advisible to slightly grease the lip of the beaker, and to use a guiding rod. Should particles of the precipitate adhere to the beaker, they may be loosened by means of a trimmed feather or a rubber-tipped glass rod. Wash the precipitate on the filter with diluted alcohol, neutral to litmus, until the washings no longer have an acid reaction. Then place the funnel, containing the filter with the precipitate, in an air-bath, and dry at a temperature of 105° C. Next transfer the precipitate from the filter to a tared crucible. This can best be accomplished by carefully unfolding the filter over a piece of perfectly clean, glazed paper, from which the precipitate can easily be transferred to the crucible. A small quantity of $Pb\,SO_4$ will adhere to the filter so that it cannot be removed. It is desirable, however, to remove the most of the precipitate from the paper in order to prevent the reduction of much of the $Pb\,SO_4$ during incineration.

Burn the filter on an inverted crucible lid, and heat until all carbon has disappeared and the ash is perfectly white. Then cool, add a few drops of diluted nitric acid, warm, add three drops of sulphuric acid, and heat until fumes cease to be given off. This again converts into sulphate any lead which may have been reduced by the incineration with the carbon yielded by the filter paper. Then, having added the mixture of filter-ash and Pb SO_4 to the bulk of the Pb SO_4 in the crucible, ignite the whole for 15 minutes, cool in a desiccator, and weigh, repeating the operation until a constant weight has been obtained.

Calculation.—From the total weight deduct the weight of the crucible used and of the filter-ash. The remainder is the weight of $PbSO_4$. Then, the molecular weight of $PbSO_4$: atomic weight of Pb :: weight of ignited precipitate ($PbSO_4$) : x. x = amount of Pb in precipitate,-hence the amount in the quantity of "unknown" operated on; for all of the Pb, no matter in what form it existed orginally, has been converted into $PbSO_4$. Then, knowing the amount of "unknown" weighed out, and the amount of Pb contained therein, the per cent of Pb may be calculated as follows:—weight taken : x :: 100 : y. y = per cent of Pb. Results should always be calculated to per cent and reported as such, since in this form they best admit of comparison.

2. DETERMINATION OF COMBINED SO_4 AS BARIUM SULPHATE.

Principle.—On mixing a solution of a soluble barium salt with a solution of a soluble sulphate, all SO_4 unites with Ba to form Ba SO_4, which precipitates: The precipitate is practically insoluble in dilute acids.

Process.—Take an exact weight (about 1 Gm.), dissolve in 15 cc. of water, acidulate with 5 cc. of diluted hydrochloric acid, add an excess of Ba Cl_2 solution (about 20 cc.), and boil for ten minutes.

$$(Met)\,SO_4 + BaCl_2 = BaSO_4 + (Met)\,Cl_2.$$

Moisten two 9 cm. fillers with water, and beat them into a pulp, using a clean mortar for the operation.

Add this pulp to the contents of the beaker, and boil for 10 minutes, replacing the water lost by evaporation. This is necessary to prevent loss of precipitate by spurting. The boiling causes the larger crystals to grow at the expense of the smaller ones, thus increasing the average size of the particles, and making complete separation of precipitate by filtration possible. The paper pulp serves to entangle the precipitate, and is another safeguard against loss of Ba SO_4 through the filter.

Allow the precipitate to subside, and decant the supernatant liquid through a filter. Wash again with boiling water, allow the precipitate to settle, and decant through the filter. Next transfer the precipitate to the filter and continue the washing with boiling water until the filtrate ceases to precipitate $AgNO_3$ solution. Then, having dried the precipitate in an air-bath, transfer to a crucible (burning the filter separately, and adding the ash), and ignite for 20 minutes. Cool, add 3 drops of concentrated H_2SO_4, and again ignite for 10 minutes. Cool in the desiccator and weigh. Repeat the operations and weighings until the last two weighings agree.

Calculation.—From the total weight deduct the weight of the crucible used and the weight of 3 filter-ashes. The difference is the weight of $BaSO_4$. Then, $BaSO_4 : SO_4 ::$ weight of ignited precipitate($BaSO_4$) : x. x = weight of SO_4 in precipitate,—hence in the "unknown" operated on. Then, weight taken : x :: 100 : y. y = per cent of SO_4.

Note—Other methods than that here given are sometimes employed to facilitate the operation of filtering Ba SO_4. Some authorities advocate the addition of NH_4 Cl, before precipitation, which renders the precipitate coarser, and therefore more easily filtered. Another method is to make use of a Gooch crucible. This consists simply of a crucible, the bottom of which is perforated by a number of small holes. A layer of moistened, finely threaded asbestos is spread out over the bottom of the crucible, and the latter is connected with a water aspirator or other form of exhaustion apparatus. The asbestos forms a compact film, covering the openings The precipitate is transferred directly from the beaker to this crucible, where it is thoroughly washed, dried, and ignited, without the need of again changing containers.

3. DETERMINATION OF IRON AS FERRIC OXIDE.

Principle.—(1) HNO_3 oxidizes ferrous iron to ferric iron; (2) ferric iron is completely precipitated as $Fe(OH)_3$ by excess of NH_4OH; (3) ~~high~~ heat converts $Fe(OH)_3$ into Fe_2O_3.

Process.—Weigh out about 1 Gm. and dissolve in 30 cc. of water, if necessary, adding HCl to form a clear solution. Add about 2 cc. of HNO_3 and heat. The reaction—oxidation—is completed when the addition of more HNO_3 produces no further change in color.

$$3FeCl_2+HNO_3+3HCl=3FeCl_3+NO+2H_2O.$$

To the warm solution add ammonia water, gradually, and with constant stirring, until the latter is in excess.

$$FeCl_3+3NH_4OH=Fe(OH)_3+3NH_4Cl$$

Boil for 2 minutes, cool, and allow the precipitate to settle. Then pour off the supernatant liquid through a filter, and wash the precipitate twice by decantation. Transfer the moist precipitate to the filter through which the washings were passed, and wash the precipitate with hot water, until a few drops of the washings, caught in a test-tube containing a few cubic centimeters of $AgNO_3$ solution, which has previously been acidified with HNO_3, cease to become cloudy.

Dry the precipitate in an air-bath and transfer to a tared crucible, burning the filter on the crucible lid and adding the ash to the contents of the crucible. Ignite to a constant weight, *i. e.*, until the precipitate ceases to lose weight on further ignition, and the last two weighings agree.

$$4Fe(OH)_3=3H_2O+Fe_4O_3(OH)_6.$$
$$Fe_4O_3(OH)_6=H_2O+4FeO(OH).$$
$$4FeO(OH)=2H_2O+2Fe_2O_3.$$

The residue now consists of Fe_2O_3.

Calculation.—Fe_2O_3 : Fe_2 :: weight of ignited precipitate : x. x = weight of iron in precipitate,—hence in weight of "unknown" taken. Then, weight taken : x :: 100 : y. y = per cent of iron.

Note.—If many determinations of the same kind are to be made, the calculations are usually shortened by ascertaining and using a so-called *analytical factor*. This is a number which indicates how much of the substance sought, is equal to one part of the substance given. For example, in one gramme of Fe_2O_3 (substance given), there is .700 Gm. of iron (substance sought). The factor for iron in case of Fe_2O_3 is therefore .7.

Finding the Factor.—Relative weight of substance given : relative weight of substance sought :: 1 : x. x = amount of substance sought which equals one part of substance given. *Example.*—The substance (ignited precipitate) finally weighed is Ca O; but Ca is to be reported. Find factor for Ca.

Ca O : Ca :: 1 : x. x = factor for Ca.
56 : 40 :: 1 : .714 .714 = factor for Ca.

Using the Factor.—Multiply the weight of the substance given (final weighing) by the factor. The product is the weight of substance sought. From this, the per cent may be calculated in the usual way. *Example.*—1.2 Gm. of an iron compound yields .73 Gm. of Fe_2O_3. Find per cent of iron, the factor for iron being .7.

.73 Gm. × .7 = .511 Gm. = amount of iron in .73 Gm. of Fe_2O_3,—hence in 1.2 Gm. of "known." Then, 1.2 Gm : .511 Gm. : : 100 : x (42.58% of iron).

4. DETERMINATION OF CALCIUM AS CALCIUM OXIDE.

Principle.—(1) Ammonium oxalate, in presence of ammonium hydroxide, completely precipitates calcium as calcium oxalate, from solutions of its salts; (2) ignition converts CaC_2O_4 first into $CaCO_3$, and finally, after high heating, into $Ca O$.

Process.—Weigh out about 1 Gm , place in a tall beaker, and add 20 cc. of water. If the "unknown" does not dissolve to a clear solution, drop in HCl until the liquid has become perfectly clear. Warm, add 30 cc. of water, and heat to about 90°C. Next, add an excess (12 cc.) of ammonium oxalate solution, and then ammonium hydroxide until its odor becomes quite noticeable.

$$CaCl_2 + (NH_4)_2C_2O_4 = CaC_2O_4 + 2NH_4Cl.$$

Stir well and set aside in a warm place for 12 hours, in order to allow the precipitate to subside. Decant the supernatant liquid through a filter, and wash the precipitate twice by decantation, always passing the washings through the filter. Then transfer the precipitate to the filter and wash thoroughly with hot water in the usual manner. [If any of the precipitate adheres to the beaker so that it cannot be removed, dissolve that portion in HCl and reprecipitate. Wash by decantation, and add to the bulk of the precipitate on the filter.]

Dry in an air-bath. Transfer to a crucible (burning the filter separately and adding its ash to the precipitate in the crucible) and ignite for a few minutes over a Bunsen flame. Then ignite in a blast-lamp flame for 20 minutes.

$$CaC_2O_4 + O = CaCO_3 + CO_2.$$
$$CaCO_3 = CaO + CO_2.$$

Cool and weigh. Repeat this operation until the last two weighings agree.

Calculation.—From the total weight, subtract the weigh of crucible and of one filter-ash. The result is the weight of Ca O. From this calculate the per cent of Ca in the original substance.

5. DETERMINATION OF MAGNESIUM AS MAGNESIUM PYROPHOSPHATE.

Principle.—(1) In the presence of ammonium chloride and ammonium hydroxide, sodium phosphate solution precipitates magnesium as ammonio-magnesium phosphate; (2) ignition converts this precipitate into magnesium pyrophosphate.

Process.—Weigh out about 1 Gm., transfer to a number 3 beaker, add 20 cc. of water, and warm. Should the "unknown" prove to be insoluble, continue to warm gently, and add HCl until a clear solution results. To this add 15 cc. of strong NH_4Cl solution, and then NH_4OH in excess. [If the solution becomes turbid, owing to the formation of $Mg(OH)_2$ (which occurs when there is a deficiency of NH_4Cl), add HCl until the turbidity disappears; then 5 cc. more of NH_4Cl solution; and finally NH_4OH to decided excess.] To the solution, which should be clear, next add 20 cc. of Na_2HPO_4 solution, mix well, and set aside for 12 hours. The precipitate, which is crystalline in nature, and has the formula, $NH_4MgPO_4 . 6H_2O$, forms quite slowly; hence the necessity for setting aside for 12 hours. Violent agitation tends to facilitate this precipitation.

$$MgCl_2 + NH_4OH + Na_2HPO_4 = NH_4MgPO_4 + 2NaCl + H_2O.$$

Filter and wash the precipitate with diluted NH_4OH (1 part to 3 parts of water) by adding a little at a time, allowing each portion to pass through completely before more is added. When a few drops of the washings, caught in a test-tube containing a few cubic centimeters of acidulated $AgNO_3$ solution, cease to become cloudy, place the precipitate in an air-bath, dry, transfer to a crucible (burning the filter separately and adding the ash), and ignite for 20 minutes.

$$2NH_4MgPO_4 = Mg_2P_2O_7 + 2NH_3 + H_2O.$$

Should the precipitate be dark in color, moisten with HNO_3, dry carefully, and again ignite for a few minutes. Cool and weigh.

When a constant weight has been obtained, the residue consists of $Mg_2P_2O_7$.

Calculation. - $Mg_2P_2O_7 : Mg_2 ::$ weight of ignited precipitate: x . x = amount of magnesium in the precipitate,—hence in the "unknown" operated on. Then calculate per cent of magnesium in the usual way.

6. DETERMINATION OF SULPHITE, THIOSULPHATE, SULPHIDE, OR FREE SULPHUR, AS BARIUM SULPHATE.

Principle.—Sulphites, thiosulphates, sulphides, and free sulphur may be converted into sulphates by means of strong oxidizing agents. The sulphur may then be determined as $Ba\,SO_4$. See exercise 2.

Process.—Take an exact weight (about 1 Gm.), place in a small evaporating dish, add about one gramme of $KClO_3$, and then, very carefully, about 5 cc. of 40 per cent. HNO_3. When the reaction has ceased, place on a water-bath and heat to 90°C. From time to time add a little $KClO_3$, continuing its addition as well as the heating, until every trace of sulphur has disappeared. Should all HNO_3 be evaporated before the oxidation is completed, add 2 or 3 cc. as required. Then evaporate off the excess of HNO_3, dissolve the residue in about 20 cc. of water, and add 5 cc. of HCl. To the resulting clear solution, add $Ba\,Cl_2$ solution in excess, *i. e.*, until a few drops added to the supernatant liquid, cease to produce a turbidity.

$$K_2SO_4 + BaCl_2 = BaSO_4 + 2KCl.$$

The precipitate, which consists of $BaSO_4$, may be prepared for weighing as directed in exercise 2.

Calculation.—Report the per cent of sulphur as sulphide, calculating as in exercise 1. [In case of thiosulphate the calculation would be,—$2BaSO_4 : S_2O_3 ::$ weight of ignited precipitate:x. Then, amount weighed out:x :: 100:y. y = per cent of S_2O_3].

7. DETERMINATION OF PHOSPHATE AS MAGNESIUM PYROPHOSPHATE.

Principle.—PO_4 may be precipitated, like Mg (see exercise 5), as ammonio-magnesium phosphate, and ignited to magnesium pyrophosphate.

Process.—Weigh out about .75 Gm., dissolve in 20 cc. of water, add 2 Gm. of NH_4Cl and enough NH_4OH to impart a distinct odor to the solution. Then add "magnesia mixture" (made by dissolving 10 Gm of $MgSO_4$ and 20 Gm. of NH_4Cl in 80 cc. of water, and adding 42 cc of NH_4OH) in excess, and stir well. Set aside for about 12 hours. Then prepare the precipitate for weighing as directed in exercise 5.

Calculation.—$Mg_2P_2O_7 : P_2O_5$ :: weight of ignited precipitate : x. Then calculate per cent of P_2O_5 in original substance. Also calculate the per cent. of PO_4 as follows, - $Mg_2P_2O_7 : 2PO_4$ :: weight of ignited precipitate : x.

VOLUMETRIC ANALYSIS.

In volumetric methods, a reagent of known strength is added to a known quantity of the substance to be determined, until a certain reaction has been effected; and from the volume of the reagent required to complete the reaction, the amount of the constituent to be estimated is found by calculation.

Principle.—When substances combine chemically, they do so in definite proportions; that is, certain relative amounts of the substances enter into combination,—and if one or the other of the reacting substances be in excess of these relative amounts, the excess will remain uncombined Thus, when $NaOH$ reacts with HCl, 39.96 parts of the first named substance always combine with exactly 36.37 parts of the acid. If a relatively greater amount of $NaOH$ be present, the mixture will turn red litmus blue, which is an indication of free $NaOH$. If, on the other hand, a relatively greater amount of HCl be present, blue litmus will be turned red, showing the presence of uncombined HCl. Hence, a solution of HCl requiring 39.96 mg (or grains, or grammes) of $NaOH$ for neutralization must contain exactly 36.37 mg. (or grains, or grammes) of absolute HCl; a solution of HCl requiring one-fourth of 39.96 parts of $NaOH$, must contain one-fourth of 36.37 parts of HCl; etc. In fact, combining number of $NaOH$: combining number of HCl :: amount of $NaOH$ required for neutralization : amount of absolute HCl in substance determined.

The reagents are always added in the form of dilute solutions of definite and known strength. These solutions, which are termed *standard solutions* or *volumetric solutions*, may be classified as follows:

CLASS A —Solutions suitable for the determination of one particular substance only. These solutions are made of a strength irrespective of the molecular weight of the active constituent, one cc. indicating a certain weight (usually 10 mg.) of the substance undergoing determination. As an example of solutions of this kind may be mentioned the potassium permanganate solution as used in iron determinations by technical chemists.

CLASS B.—Solutions suitable for the determination of any substance with which the reagent produces a reaction, the completion of which is, or can be made, manifest to the operator. The strength of a solution of this class bears a simple relation to the combining number of the active constituent.

Subclass (*1*).—*Normal solutions*,—$\frac{n}{1}$, *i. e.*, $\frac{\text{normal}}{1}$.—These are made of such strength that one liter contains a number of grammes of the active ingredient equal to the molecular weight of the reagent, reduced to the valence corresponding to one atom of hydrogen. For example, the molecular weight of an acid is divided by the number which expresses the basicity of the acid; *i. e.*, the number which indicates how many free affinities ("bonds") the free acid radical would have. This quotient expressed in grammes is the amount of absolute acid required to make one liter. Thus, H_2SO_4 is dibasic, and one molecule neutralizes two molecules of any monacid base; hence, the molecular weight of H_2SO_4 must be divided by two. HCl is monobasic and must be divided by one; H_3PO_4 is tribasic and must be divided by three; etc. In like manner, the molecular weight of an alkali is divided by the number that expresses the affinities which the basylous element or radical in the alkali possesses. Thus, the molecular weight of NaOH must be divided by one; that of $Ba(OH)_2$ by two; etc. But if more than one atom of a basylous element be present in the formula, the total number of affinities possessed by the two or more atoms must be used as the divisor. The molecular weight of Na_2CO_3 is therefore divided by two. In case of precipitants, the affinities of the element or radical (basylous or acid) which unites with an element or radical of the substance acted upon with the formation of a precipitate, indicate by what number the molecular weight must be divided. Thus, $Na\,(Cl)'$ and $(Ag)'\,NO_3$ are divided by one; $K_2\,(CrO_4)''$ and $(Ba)''\,Cl_2$ by two; etc.

Note.—These directions for determining the "hydrogen equivalent" are not applicable to oxidizing or reducing agents such as $K_2Cr_2O_7$, $K_2Mn_2O_8$, I_2, $FeSO_4$, As_2O_3, $Na_2S_2O_3$, etc., for which special directions will be given.

Normal solutions are made to contain, in each liter, not the molecular weight expressed in grammes, but the molecular weight divided by the number of "hydrogen equivalents," expressed in grammes; because it greatly simplifies calculations to have all $\frac{n}{1}$ solutions of uniform strength,—one cc. of any $\frac{n}{1}$ solution exactly equaling one cc. of any other $\frac{n}{1}$ solution in neutralizing ability. This would not be the case if the molecular weights were used without dividing by the number of "hydrogen equivalents"; for then $\frac{n}{1}$ H_2SO_4 solution would be twice as strong as $\frac{n}{1}$ HCl solution, and $\frac{n}{1}$ $Ba\,(OH)_2$ solution would be twice as strong as $\frac{n}{1}$ NaOH or KOH solution.

Subclass (2)—Decinormal solutions—$\frac{n}{10}$. These are of $\frac{1}{10}$ the strength of normal solutions.

Subclass (3)—*Centinormal solutions*—$\frac{n}{100}$. These are of $\frac{1}{100}$ the strength of normal solutions.

Other strengths in use are *quintinormal*—$\frac{n}{5}$; *seminormal*—$\frac{n}{2}$; *double-normal*—$\frac{2}{n}$; etc.

FACTORS.

The volumetric factor of any substance is the weight of the substance (expressed in grammes) which one cc. of its volumetric solution should contain. Just as there are normal, decinormal, centinormal solutions, so there are also normal, decinormal, centinormal factors. Since all $\frac{n}{1}$ solutions exactly equal each other, cc. for cc., the $\frac{n}{1}$ factor of any substance expresses how much of that particular substance is indicated by 1 cc. of any $\frac{n}{1}$ solution with which the substance is capable of reacting. For example: .05599 Gm. is the $\frac{n}{1}$ factor for KOH, this being the amount of KOH in 1 cc. of its $\frac{n}{1}$ solution. But .05599 Gm. is also the amount which exactly neutralizes, and hence is indicated by, one cc. of $\frac{n}{1}$ HCl or $\frac{n}{1}$ H_2SO_4, or in fact, any $\frac{n}{1}$ solution capable of neutralizing KOH. Thus, a solution of KOH requiring 20 cc. of $\frac{n}{1}$ acid for neutralization, must contain [.05599 Gm. × 20] .11198 Gm. of KOH.

Note.—In the pharmacopoeia, calculations are simplified by taking such an amount of the substance examined as bears a simple relation to its molecular weight. Each cc. of the volumetric solution used usually indicates one per cent.

INDICATORS.

Since the amount of active constituent in the substance operated on is calculated from the volume of the standard solution which will exactly complete a certain reaction with the substance, it is necessary that the completion of the reaction be manifest to the operator. In some cases, either the reagent or the substance being determined undergoes a visible change when the reaction is complete. But in most cases, the completion of the reaction cannot be seen; and the "end-reaction" must be rendered visible by adding some substance which does undergo some visible change, either with the reagent or with the substance being determined. Substances which thus serve to indicate the end of the reaction are called *indicators.* (See the United States Pharmacopoeia, page 472).

APPARATUS.

1. Burettes.—Those provided with a glass stop-cock are used for acids and oxidizing agents, and must never be used for alkalies. Burettes terminating in a rubber tube provided with a pinch-cock, are intended for alkalies, but may also be used for other substances which have no action on rubber.

2. Floats.—These serve the purpose of doing away with the meniscus, so that the height of the column of liquid in the burette may be read with great accuracy.

3. Graduated Flasks and Cylinders.—The graduations on these are not always absolutely correct. The accuracy of these measures should always be tested before they are made use of in diluting volumetric solutions. The operator should also have several small flasks, graduated to hold 60, 80, or 100 cc. The graduating mark should be on the neck of the flask, and not on the shoulder or body.

PREPARATION OF VOLUMETRIC SOLUTIONS.

The volumetric solutions of such substances as can be obtained in a definite and permanent form, are made by simply dissolving the theoretical weight of the substance (see pages 17 and 18) and diluting to the proper volume.

DECINORMAL SOLUTION OF OXALIC ACID.

Calculation.—Figure the molecular weight ($H_2C_2O_4 \cdot 2H_2O = 125.7$). Divide by two because oxalic acid is dibasic; hence has two "hydrogen equivalents" ($125.7 \div 2 = 62.85$). Divide by ten, because a *deci*normal, and not a normal solution is to be made ($62.85 \div 10 = 6.285$). Express in grammes (6.285 Gm.). This is the amount for one liter.

Process.—Weigh out 6.285 Gm. of pure, freshly crystallized, and carefully dried oxalic acid. Carefully transfer to a 1000 cc. cylinder or measuring flask. Dissolve in 200 or 300 cc. of distilled water, cool to 15° C., and dilute to exactly 1000 cc., using distilled water cooled to the same temperature. Preserve the volumetric solution in a securely corked bottle and in a cool place. Oxalic acid volumetric solution is not permanent, becoming weaker on keeping. It may also crystallize out to a certain extent at the point of the burette. For these and other reasons, it is not well adapted for general use; but because of the ease with which it can be prepared, it is largely used for standardizing other solutions.

DECINORMAL SOLUTION OF POTASSA.

Principle.—Potassa cannot readily be obtained of definite strength or purity, owing to its hygroscopicity and its affinity for CO_2. Hence, volumetric solutions of KOH cannot be made by simply dissolving the theoretical weight and diluting to the theoretical volume, but must be brought to the proper strength by standardizing against an acid solution of *known* standard strength.

Process.—Weigh out the theoretical quantity of KOH for one liter of solution. Transfer to a one liter cylinder. Dissolve in about 200 cc. of distilled water, cool to 15°C., and, by the addition of distilled water at the same temperature, dilute to one half the theoretical volume, *i. e.*, dilute to 500 cc. It is assumed that the potassa used contains more than 50% of absolute KOH. The solution is therefore too strong. But before diluting any further, determine *how much* too strong it is, by ascertaining its neutralizing power by comparison with $\frac{n}{10}$ oxalic acid solution.

All $\frac{n}{10}$ acids must be exactly equivalent to each other in strength,—cc. for cc.—one cc. of one having the same neutralizing power as one cc. of any other $\frac{n}{10}$ acid. This also holds good in case of alkalies. Moreover, one cc. of any $\frac{n}{10}$ acid is exactly equivalent to one cc. of any $\frac{n}{10}$ alkali. Hence the KOH solution of unknown strength can be made $\frac{n}{10}$ by simply diluting until one cc. exactly neutralizes one cc. of the oxalic acid solution which is *known* to be $\frac{n}{10}$.

Proceed as follows:

Put some of the $\frac{n}{10}$ acid solution into a burette provided with a glass stop-cock; and some of the KOH solution into one of the other kind. [These burettes must be firmly supported in a perpendicular position by means of clamps. They should also be rinsed out with portions of the respective solutions with which they are to be filled, and the rinsings thrown away.] Next insert a float into each burette, taking care that it rests in the liquid perpendicularly and without retaining air bubbles. Draw off a little solution from each burette, so as to fill the same to the lower orifice and to expel air bubbles, which frequently occur in the delivery tubes as well as in the rubber tubes of burettes. Record the height of column of liquid in each burette. Then run out into a small flask or beaker, 10 cc. of the $\frac{n}{10}$ oxalic acid solution. Add three drops of phenolphtalein solution (indicator,—colorless with acids—rose-red with alkalies), and then run in the KOH solution as follows:

Five cc. may be added at once; then the liquid should be boiled for two minutes. More KOH solution must then be added, a few drops at a time, with boiling after each addition, until a pale pink tint appears, indicating that all acid has been neutralized, and that the alkali is in very slight excess. One drop of the acid solution should completely discharge the color, in which case the excess of alkali is so slight that it may be wholly ignored. Should, however, the one drop of acid solution be inadequate to completely discolor the liquid, the addition of the former must be continued until the point is reached where one drop of the acid solution discharges the color and one drop of the alkali restores it.

Now take the reading of the "acid burette" and from it, subtract the reading previously recorded. The difference is the volume of $\frac{n}{10}$ acid used in the operation. In a like manner, ascertain the volume of KOH solution used. But before basing any calculations on these data, the operation should be twice repeated to verify the first results obtained.

Notes.—(1) The process of determining the amount, or strength, of a substance by means of a volumetric solution, measured from a burette, is called *titration*.

(2) The titration in the preceding process is carried on at a boiling temperature for the purpose of expelling the CO_2, liberated from K_2CO_3, which is an ever-present constituent of ordinary potassa. CO_2, reacting acid with phenolphtalein, would introduce an error, and must therefore be driven off by boiling.

(3) Titrations should be conducted with the solutions in the burettes at as nearly 15°C. as possible; and in the preceding titration care should be exercised lest in the operation of expelling the CO_2, the liquid in the burette be warmed and consequently expanded.

The three titrations should agree with each other within $\frac{1}{10}$ cc. Should there be a greater variation, more titrations must be made until the last three practically coincide with each other.

Calculating the Dilution.—Suppose 10 cc. of $\frac{n}{10}$ oxalic acid solution neutralized 7.8 cc. of the KOH solution. The latter is obviously too strong, 7.8 cc. containing as much active constituent as 10 cc. of an $\frac{n}{10}$ solution should contain. In order, therefore, to reduce the solution to $\frac{n}{10}$ strength, each 7.8 cc. must be diluted to 10 cc. Suppose there remained 640 cc. of the KOH solution to dilute; the calculation would then be,—7.8 cc. : 10 cc. : : 640 cc. : x [820.5 cc.]. Since the 640 cc. contain as much active constituent as is contained in 820.5 cc. of a solution of $\frac{n}{10}$ strength, it is clear that by diluting the solution to that point (640 cc. to 820.5 cc.), the strength is reduced to decinormal. After the dilution has been made, the KOH solution should not be accepted as $\frac{n}{10}$ until it has again been subjected to a series of titrations and thus proved to be so by experiment. [This is necessary because a slight mistake is easily made in reading the volume of the solution in the cylinder, before and after dilution. Moreover, the graduations on some cylinders are not accurately true.] $\frac{n}{10}$ KOH solution is best preserved in a bottle provided with a siphon, the air entering the bottle being made to pass through a tube containing soda-lime or potassa for the purpose of abstracting the CO_2, as otherwise some KOH would be converted into K_2CO_3.

DECINORMAL SOLUTION OF HYDROCHLORIC ACID.

Process.—To 4.5 cc. of strong HCl contained in a graduated cylinder, add about 375 cc. of distilled water. Mix well, and cool to about 15°C. Transfer some of the solution to a clean burette [first having rinsed out the burette with a portion of the solution, throwing the rinsings away], and measure out 10 cc. from the same, into a small flask. Add two drops of phenolphtalein solution, and then run in $\frac{n}{10}$ KOH solution until a permanent pale rose color has appeared, the titration being conducted at a boiling temperature (see pages 21 and 22).

Calculation for dilution.—Number of cc. of HCl solution taken for titration : number of cc. of $\frac{n}{10}$ KOH required for neutralization :: volume of HCl solution left for dilution : x. x = the volume *to* which the remaining HCl solution must be diluted. Suppose that 10 cc. of the HCl solution required, 12 cc. of $\frac{n}{10}$ KOH for neutralization, and that 360 cc. of the HCl solution remained for dilution. Then,—10 cc. : 12 cc. :: 360 cc. : x (432 cc). The 360 cc. should therefore be diluted to 432 cc. But before using the solution, prove its strength by experiment. (See page 22).

Decinormal Solution of Sulphuric Acid.

Process.—Put 2.5 cc. of concentrated sulphuric acid into a porcelain dish, add 50 cc. of distilled water, mix well, and cool to 15°C. Transfer to the graduated cylinder and add enough distilled water (at 15°C.) to make the solution measure 400 cc. Then standardize against $\frac{n}{10}$ KOH at a boiling temperature, conducting the titration and calculation for dilution just as in making $\frac{n}{10}$ HCl solution.

Decinormal Solution of Barium Hydroxide.

Process.—Weigh out the theoretical quantity of pure crystallized $Ba(OH)_2$ for 500 cc. Dissolve in distilled water and dilute to 400 cc. Cool to 15°C. and standardize against $\frac{n}{10}$ acid, conducting the titrations, and subsequent calculation for dilution, as directed for $\frac{n}{10}$ KOH solution. To prevent absorbtion of CO_2 by the finished solution, it should be preserved under a layer of benzine, or as directed for $\frac{n}{10}$ KOH solution, in a bottle provided with a siphon, operated with air free from CO_2.

ANALYSIS BY NEUTRALIZATION.

Acidimetry,—The Determination of Acids.

DETERMINATION OF H_2SO_4 IN COMMERCIAL SULPHURIC ACID.

Process.—Put about 1 cc. into a clean, dry weighing flask, the tare of which has been ascertained, and which has been graduated to hold a certain even number of cc. at 15°C. Weigh accurately. Deduct the weight of flask from the total weight, and record the net weight of the contents. [As results are to be calculated to percentage, the substance must be weighed out,—not measured.] Next add about 40 cc. of distilled water; mix well; cool to 15°C.; and by the addition of distilled water at the same temperature, dilute up to the volume that the flask is graduated to hold,—100 cc. is the most convenient volume. Insert a clean, accurately fitting stopper and mix by shaking well. Then transfer 10 cc., measured from a burette or pipette, to a small flask; add two drops of phenolphtalein solution, and titrate against $\frac{n}{10}$ KOH solution, at a boiling temperature.

$$H_2SO_4+2KOH=K_2SO_4+2H_2O.$$

Check results by making duplicate titrations.

Calculation.—(1). Figure the $\frac{n}{10}$ factor of the substance to be determined (H_2SO_4). (2). Multiply this $\frac{n}{10}$ factor by the number of cc. of $\frac{n}{10}$ solution of the opposite kind, required for neutralization. (3). From the product thus obtained, which shows the amount of active constituent in the amount titrated, calculate the amount of active constituent in the amount weighed out, dissolved, and diluted to the mark on the flask. The calculation is indicated by the following proportion:

Number of cc. taken for titration : total no. of cc. of dilution :: amount of active constituent found in amount titrated : x. Then x = amount of active constituent in amount weighed out. (4.) From the amount of active constituent in the amount weighed out, calculate the percentage, and report the same.

Example.—Suppose two Gm. of commercial sulphuric acid had been weighed out and diluted to 90 cc. Of this, 10 cc. had been titrated, and had required 40 cc. of $\frac{n}{10}$ alkali solution for neutralization. Calculate the per cent of H_2SO_4.

(1). $H_2SO_4=98$, molecular weight. $98\div2=49$, combining number. 49 Gm. $\div$ 10,000 = .0049 Gm., $\frac{n}{10}$ factor.

(2). .0049 Gm. × 40 (no. of cc. of $\frac{n}{10}$ alkali required) = .196 Gm. (absolute H_2SO_4 in the 10 cc. of dilution subjected to titration).

(3). 10 cc. (taken for titration) : 90 cc. (total dilution) :: .196 Gm. : 1.764 Gm.; or simply, - .196 Gm. × 9 (since 10 cc. is 1/9 of the whole amount of the dilution) = 1.764 Gm. (amount of absolute H_2SO_4 in amount of commercial acid weighed out).

(4). 2 Gm. (amount weighed out) : 1.764 Gm. (H_2SO_4 contained therein) :: 100 : 88.2. The acid therefore contained 88.2% of absolute H_2SO_4.

DETERMINATION OF $HC_2H_3O_2$ IN DARK VINEGAR.

Process—Weigh out about 10 Gm. and dilute to the mark on the flask. Take an aliquot part ($\frac{1}{10}$), and run in $\frac{n}{10}$ $Ba(OH)_2$ solution, measured from a burette, until a drop of the liquid will produce a pink spot on phenolphtalein paper.

$$2HC_2H_3O_2+Ba(OH)_2=Ba(C_2H_3O_2)_2+2H_2O.$$

Note.—The use of indicator paper is recommended in case of dark liquids in which the color changes of the indicator would not be plainly visible. This paper is prepared by immersing strips of filter paper in very dilute (1 : 1000) phenolphtalein solution, and allowing them to dry. The paper is not as satisfactory as the indicator in solution.

Calculation.—Figure the $\frac{n}{10}$ factor for acetic acid ($HC_2H_3O_2$). Then follow the steps in the calculation as outlined under Determination of H_2SO_4. Report per cent of $HC_2H_3O_2$.

Note.—Some standard solutions, such as $Ba(OH)_2$ solution, become weaker on keeping, owing to the absorption of CO_2, etc. Instead of again fortifying them to standard strength, it is more expedient to simply determine how much too weak they are, and to modify the calculation accordingly.

Suppose that Ba $(OH)_2$ solution had weakened so that 10 cc. require but 9 cc. of $\frac{n}{10}$ acid for neutralization. Then each cc. of the $Ba(OH)_2$ solution is equivalent to .9 cc. of $\frac{n}{10}$ $Ba(OH)_2$ solution. This weak $Ba(OH)_2$ solution may be used; but before making the usual calculations, the number of cc. used should be multiplied by .9 (correction factor). Thus, if 15 cc. had been used in the titration, the factor of the "unknown" should be multiplied by (15×.9) or 13.5, instead of by 15.

Alkalimetry,—The Determination of Alkalies.

DETERMINATION OF Na_2CO_3 IN COMMERCIAL SODIUM CARBONATE.

Process.—Weigh out about .5 Gm.; dissolve in distilled water; and dilute to the mark on the flask. Take $\frac{1}{10}$ of this solution; add phenolphtalein indicator; run in an excess of $\frac{n}{10}$ H_2SO_4, *i. e.*, a little more than enough to destroy the pink color; and boil for from 3 to 5 minutes to expel CO_2. Should the pink tint re-appear on boiling, add more $\frac{n}{10}$ H_2SO_4 solution until the latter is in excess.

$$Na_2CO_3+H_2SO_4=Na_2SO_4+H_2O+CO_2.$$

Note the total amount of H_2SO_4 solution used. Next, "titrate back" with $\frac{n}{10}$ KOH, *i. e.*, run in $\frac{n}{10}$ KOH solution until the excess of acid has been neutralized, which is indicated by the re-appearance of the rose-red color.

$$H_2SO_4+2KOH=K_2SO_4+2H_2O.$$

Calculation.—Subtract the amount of $\frac{n}{10}$ KOH solution required for the neutralization of the excess of acid, from the total amount of acid used. The difference is the amount of acid required to neutralize the Na_2CO_3 in the amount of "unknown" titrated. Then calculate in the usual way and report per cent of Na_2CO_3.

DETERMINATION OF NH_3 IN AMMONIA WATER.

Process.—Put about 4 cc. into a stoppered weighing bottle of known tare; weigh accurately; and dilute to the mark on the bottle. Transfer an aliquot part of this dilution to a flask of convenient size; add three drops of rosolic acid indicator (yellow with acids,—reddish-violet with alkalies); and run in an excess of $\frac{n}{10}$ H_2SO_4.

$$2NH_4OH+H_2SO_4=(NH_4)_2SO_4+2H_2O.$$

Then titrate back with standard alkali ($\frac{n}{10}$ KOH), adding the latter until the reddish-violet color has re-appeared. Take the readings, calculate in the usual way, and report per cent of ammonia, which has one hydrogen equivalent.

Notes.—(1) By adding an excess of $\frac{n}{10}$ acid, we prevent the evaporation, during titration, of NH_3, which is very volatile.

(2) Phenolphtalein cannot be used as an indicator for ammonia, because neutral ammonium salts are not neutral to this indicator.

DETERMINATION OF K_2CO_3 IN OFFICIAL POTASSIUM CARBONATE.

Process.—Weigh out about .3 Gm.; dissolve in 5 cc. of water; and titrate against standard H_2SO_4, using three drops of methyl-orange solution as indicator. When the liquid has changed in color from a yellow to a crimson, enough acid has been added.

$$K_2CO_3+H_2SO_4=K_2SO_4+H_2O+CO_2.$$

As the transition from yellow to crimson is gradual, it is advisable to make methyl-orange solutions of known acidity and alkalinity having the same volume of liquid and the same amount of indicator in each solution and also in the "unknown" to be titrated, and to use these solutions for comparison in determining the end-reaction. Calculate and report per cent of K_2CO_3.

Note.—Methyl-orange is very susceptible to mineral acids, but not to organic acids, in the titration of which it cannot be used. Methyl-orange is specially valuable because, unlike phenolphtalein, rosolic acid, etc., it is not affected by CO_2; and by its use, carbonates can be titrated in the cold.

DETERMINATION OF $NH_4HCO_3.NH_4NH_2CO_2$ IN OFFICIAL AMMONIUM CARBONATE.

Principle.—The United States Pharmacopoeia directs titration against standard H_2SO_4 in the usual manner, using rosolic-acid as indicator. But rosolic-acid is sensitive to CO_2; and in boiling off the latter, some NH_3 would be driven off, if the "unknown" should be in excess. This loss of NH_3 may be prevented by "fixing" the NH_3 in adding a measured excess of standard acid.

Process.—Weigh out about 1 Gm.; dissolve; and dilute to the mark on the flask. To 1/10 of this dilution, add a measured excess (about 25cc.) of $\frac{n}{10}$ H_2SO_4, and boil gently for five minutes in order to expel all CO_2. Then add 8 drops of litmus solution, and run in $\frac{n}{10}$ KOH until the reddish colored solution has turned to a violet-blue.

$$2NH_4HCO_3NH_4NH_2CO_2+3H_2SO_4=3(NH_4)_2SO_4+2H_2O+4CO_2$$

Calculation.—Subtract the number of cc. of $\frac{n}{10}$ KOH required by the excess of acid, from the total amount (25 cc.) of acid used. The difference is the amount of $\frac{n}{10}$ acid required by the amount of "unknown" titrated. One molecule of ammonium carbonate is chemically equivalent to three molecules of any monobasic acid; hence its molecular weight must be divided by three in figuring the $\frac{n}{10}$ factor. Calculate in the usual way, and report per cent of $NH_4HCO_3.NH_4NH_2CO_2$.

DETERMINATION OF THE METALLIC SALT OF AN ORGANIC ACID,—SODIUM ACETATE.

Principle.—Prolonged ignition converts the metallic salts of the organic acids,—acetates, citrates, oxalates, benzoates, salicylates, etc.,—into carbonates, which may be determined by titration against standard acid, the latter indicating the amount of organic salt which would yield the amount of carbonate found.

Process.—Weigh out in a tared crucible, about 2 Gm., and ignite in a Bunsen flame until completely charred. Extract the black residue repeatedly with small quantities of boiling water, filtering the resulting solution of Na_2CO_3 into a small graduated flask. Lastly, transfer the residue to the filter, and percolate with boiling water until the filtrate fills the flask to the mark. Cool; add water to make up for the contraction; and mix well. Then take an aliquot part (1/10); add three drops of phenolphtalein solution; and run in an excess of $\frac{n}{10}$ H_2SO_4 solution.

$$Na_2CO_3+H_2SO_4=Na_2SO_4+CO_2+H_2O.$$

Boil for five minutes to expel CO_2, and titrate back with $\frac{n}{10}$ KOH.

$$H_2SO_4+2KOH=K_2SO_4+2H_2O.$$

Calculation.—As all of the metallic salt has been converted, before titration, into carbonate, the calculation is quite simple, the carbonate requiring just as much acid as the amount of organic salt yielding the carbonate *would require*, could this salt be titrated directly. The carbonate may therefore be entirely ignored in the calculation.

The organic salt operated on has as many hydrogen equivalents as its metallic base has affinities. [Thus, in finding the factor for sodium acetate, $NaC_2H_3O_2$, divide the molecular weight by one (which is equivalent to not dividing it at all); for sodium tartrate, $Na_2C_4H_4O_6$, divide by two; for sodium citrate, $Na_3C_6H_5O_7$, divide by three; etc.] Calculate in the usual way, and report per cent of $NaC_2H_3O_2$.

DETERMINATION OF $CaBr_2$ IN OFFICIAL CALCIUM BROMIDE.

Principle.—Some neutral salts are decomposable by acids or alkaline carbonates with the formation of products which are neutral in reaction. For example:

$$CaCO_3+2HCl=CaCl_2+H_2O+CO_2.$$
$$CaBr_2+Na_2CO_3=CaCO_3+2NaBr.$$

[The CO_2 in the first equation, is boiled off].

To such salts, titration against acids or alkaline carbonates is applicable.

Process.—Weigh out about 3 Gm.; dissolve; and dilute to the mark on the flask. Take 1/10; heat to boiling; add three drops of phenolphtalein solution, and run in $\frac{n}{1}$ Na_2CO_3 solution until a pink color appears.

$$CaBr_2+Na_2CO_3=CaCO_3+2NaBr.$$

Calculation.—Figure the *normal* factor for $CaBr_2$; and then calculate in the usual way. Report per cent of $CaBr_2$.

Note.—$\frac{n}{1}$ Na_2CO_3 is made by igniting pure, dried sodium carbonate at a red heat for 10 minutes, cooling in a desiccator, weighing out 13.232 Gm., and dissolving to make 250 cc. of solution.

ANALYSIS BY OXIDATION AND REDUCTION.

Just as the amount of an alkali is indicated by the amount of an acid necessary for neutralization, so the amount of an oxidizable substance is indicated by the amount of an oxidizing agent necessary for complete oxidation; and in a like manner, the amount of a reducible substance is indicated by the amount of a reducing agent necessary for complete reduction.

Oxidation.

By oxidation is understood not only the addition of oxygen to a molecule, as is represented by the equation,—$2FeO+O=Fe_2O_3$; but also the increase in valence of atoms in the molecule, as in the converting of $FeCl_2$ to $FeCl_3$. All oxidizable substances are capable of reducing certain other substances; and all reducible substances may act as oxidizing agents, *i. e.*, have oxidizing power. But it must be remembered that a substance may be an oxidizing agent in some cases, and a reducing agent in others.

In volumetric analysis, $K_2Cr_2O_7$, $KMnO_4$, and I_2, are the most important oxidizing reagents. The first two named are capable of yielding nascent oxygen, while Iodine acts by liberating nascent oxygen from water. Of the seven atoms of O in one molecule of $K_2Cr_2O_7$, three are avaible for oxidizing purposes.

$$K_2Cr_2O_7+4H_2SO_4=K_2SO_4+Cr_2(SO_4)_3+4H_2O+3O.$$

Since these three atoms of O are chemically equivalent to six atoms of H, one molecule of $K_2Cr_2O_7$ is chemically equivalent to six atoms of H, and in finding its factor, or in calculating the quantity for making volumetric solutions, the molecular weight of $K_2Cr_2O_7$ must be divided by six. Of the eight atoms of O in $(KMnO_4)_2$ or $K_2Mn_2O_8$, five are available for oxidizing purposes.

$$K_2Mn_2O_8+3H_2SO_4=K_2SO_4+2MnSO_4+3H_2O+5O.$$

Hence $K_2Mn_2O_8$ is chemically equivalent to ten atoms of H, and in finding the factor, etc., the molecular weight of $K_2Mn_2O_8$ must be divided by ten. Iodine is chemically equivalent to one atom of H, as is shown by the following equation:

$$I_2+H_2O=2HI+O.$$

STANDARD SOLUTIONS

DECINORMAL SOLUTION OF POTASSIUM PERMANGANATE.

Process.—Dissolve 3.5 Gm. of pure crystallized potassium permanganate in 1000 cc. of boiling water. Set the solution aside for two days; then decant the clear liquid from the deposit. Next titrate the solution against $\frac{n}{10}$ oxalic acid solution as follows:

From a burette, run out 10 cc. of $\frac{n}{10}$ oxalic acid solution into a small flask; add 4 cc. of 25% H_2SO_4; warm to about 65°C.; and then run in the $KMnO_4$ solution from a burette (provided with a glass stop-cock) until the reagent is no longer decolorized, and the solution has acquired a pinkish tint.

$$K_2Mn_2O_8 + 5H_2C_2O_4 + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 8H_2O + 10CO_2.$$

Should 10 cc. of the $KMnO_4$ solution be required for the 10 cc. of $\frac{n}{10}$ $H_2C_2O_4$ solution, the first-named would also be $\frac{n}{10}$. Should it prove stronger or weaker, however, do not dilute or fortify, but calculate the modified factor (correction factor), proceeding as directed on page 25.

Potassium permanganate solution may also be standardized against $FeSO_4$. But as $FeSO_4$ cannot readily be obtained chemically pure, free from moisture, and with a known amount of water of crystallization, the $FeSO_4$ is usually made for the occasion from a calculated amount of pure iron.

Process.—Weight out exactly .1118 Gm. of iron wire; put into a small measuring flask, so stoppered and arranged as to allow the escape, through a slit in a rubber tube, of the hydrogen generated, but to exclude the air, which would oxidize some iron. Next add 8 cc. of 25% H_2SO_4, diluted with an equal volume of water, and warm until all metallic iron has dissolved to form $FeSO_4$.

$$Fe + H_2SO_4 = FeSO_4 + H_2.$$

Then dilute to the mark on the flask with water recently boiled in order to expel absorbed air. Mix well and divide into two equal portions, each of which is equivalent to ten cc. of an $\frac{n}{10}$ solution of $FeSO_4$. [The $\frac{n}{10}$ factor for Fe is .005588. Ten cc. of the $\frac{n}{10}$ solution of $FeSO_4$ would therefore contain .05588 Gm. of iron,—just ½ of the amount of iron wire weighed out.] Each portion would require 10 cc. of $\frac{n}{10}$ $KMnO_4$ for oxidation; and therefore, from the amount required, of the $KMnO_4$ solution examined, the strength of the latter can be calculated. The titration should be made as follows:

To one portion of the $FeSO_4$ solution, representing 10 cc. of an $\frac{n}{10}$ solution, add 5 cc. of 25% H_2SO_4, and then from a burette, run in the $KMnO_4$ solution to be tested, until the solution acquires a pink tint.

$$10FeSO_4 + K_2Mn_2O_8 + 8H_2SO_4 = 5Fe_2(SO_4)_3 + 2MnSO_4 + K_2SO_4 + 8H_2O.$$

Make a duplicate titration with the other half of the $FeSO_4$ solution, and then calculate the "correction factor" for the $KMnO_4$ solution in the usual way.

Notes.—(1.) Titrations with $KMnO_4$ solution must be made in the presence of an excess of H_2SO_4, in order to prevent the precipitation of oxides of manganese, which would obscure the end reaction. An excess is necessary because $MnSO_4$ in neutral solution, acts as a reducing agent.

(2.) As $KMnO_4$ acts on rubber, a glass stop cocked burette must be used for this solution. The solution should not be allowed to remain in the burette or in a glass-stoppered cylinder for any great length of time, as the solution attacks the ground glass surface, causing the stoppers to stick tightly.

DECINORMAL SOLUTION OF POTASSIUM DICHROMATE.

Process.—Weigh out 2.5 Gm. of pure $K_2Cr_2O_7$; dissolve; and dilute to 500 cc. Weigh out .1118 Gm. of iron wire, and dissolve to $FeSO_4$, following the directions given under Decinormal Solution of Potassium Permanganate, page 31. Divide the solution into two equal portions, each containing as much $FeSO_4$ as would be contained in 10 cc. of an $\frac{n}{10}$ solution. Use the two portions for duplicate titrations, which are best made as follows:

To the $FeSO_4$ solution contained in a flask, add $K_2Cr_2O_7$ solution from a glass stop-cocked burette, until a drop of the liquid no longer gives a blue color with a drop of freshly prepared potassium ferricyanide solution. The $K_3Fe(CN)_6$ test solution should be used on a pill-tile, onto which it is best dropped by means of a glass rod, so as to form a row of dots. When about 8 cc. of the $K_2Cr_2O_7$ solution have been added, stir well, and by means of the stirring rod, convey a drop of the liquid to the first dot of indicator on the pill-tile. If a blue color is produced, add more $K_2Cr_2O_7$ solution, and again test, this time transferring the drop of liquid to the second dot of indicator on the tile.* Continue in this manner, adding $K_2Cr_2O_7$ solution in small quantities, and testing after each addition (using a fresh dot of indicator for each test), until the liquid ceases to produce a bluish or greenish color, and colors the dot brown.

$$6FeSO_4+K_2Cr_2O_7+7H_2SO_4=K_2SO_4+Cr_2(SO_4)_3+7H_2O+3Fe_2(SO_4)_3.$$

$$3FeSO_4+2K_3Fe(CN)_6=Fe_3[Fe(CN)_6]_2+3K_2SO_4.$$

Then take the reading; and from the amount of $K_2Cr_2O_7$ solution required to oxidize the $FeSO_4$, calculate its strength.

DECINORMAL SOLUTION OF IODINE.

Process.—Weigh out 4.218 Gm. of pure, resublimed iodine (for process of purification, see the United States Pharmacopoeia, page 485) and 7.5 Gm. of potassium iodide. Dissolve in 100 cc. of distilled water, and dilute to 333⅓ cc., adding the last 3⅓cc. from a burette.

Note.—The KI is used merely to effect the solution of I_2, which is practically insoluble in water, but dissolves in KI solution.

DETERMINATIONS.

DETERMINATION OF $FeSO_4$ IN FERROUS SULPHATE SOLUTION.

Process.—Weigh out about 10 Gm. and dilute to the mark on the flask. To 1/10 of this dilution, add 5 cc. of 25% H_2SO_4, and then standard $KMnO_4$ solution until a permanent pink tint is produced, showing the oxidizing reagent ($KMnO_4$) to be in slight excess.

$$10FeSO_4+K_2Mn_2O_8+8H_2SO_4=5Fe_2(SO_4)_3+2MnSO_4+K_2SO_4+8H_2O.$$

Calculation.—From the equation given above, it may be seen that $FeSO_4$ is chemically equivalent to one atom of H, since 10 molecules react with 1 molecule of $K_2Mn_2O_8$, which has 10

**Note.*—The stirring rod must always be cleaned from indicator before it is again used to stir the liquid.

hydrogen equivalents. Accordingly figure the $\frac{n}{10}$ factor for $FeSO_4$; calculate in the usual way; and report the per cent found. Also calculate and report the per cent of $FeSO_4.7H_2O$.

DETERMINATION OF $FeSO_4$ IN FERROUS SULPHATE SOLUTION.

Process.—Weigh 10 cc. of the solution; dilute to the mark on the flask; and take 1/10 for titration against standard $K_2Cr_2O_7$ solution, using $K_3Fe(CN)_6$ solution as indicator. Conduct the titration as directed under Decinormal Solution of Potassium Dichromate, pages 32 and 33.

$$6FeSO_4+K_2Cr_2O_7+7H_2SO_4=3Fe_2(SO_4)_3+Cr_2(SO_4)_3+K_2SO_4+7H_2O.$$

Calculation.—In the equation with $K_2Cr_2O_7$, just as in the one with $K_2Mn_2O_8$, $FeSO_4$ is shown to have one hydrogen equivalent. Calculate accordingly, and report per cent of $FeSO_4$ and of $FeSO_4.7H_2O$.

DETERMINATION OF $Ca(PH_2O_2)_2$ IN OFFICIAL CALCIUM HYPOPHOSPHITE.

Process.—Weigh out about 1 Gm.; dissolve; and dilute to the mark on the flask. Take 1/10 of the dilution; add 10 cc. of 25% H_2SO_4; and then run in a measured excess (50 cc.) of $\frac{n}{10}$ $KMnO_4$ solution. Boil for 15 minutes.

$$5Ca(PH_2O_2)_2+4K_2Mn_2O_8+17H_2SO_4=5CaSO_4+10H_3PO_4+4K_2SO_4+8MnSO_4+12H_2O.$$

Then determine the excess of $KMnO_4$ solution by titrating back with $\frac{n}{10}$ $H_2C_2O_4$ solution.

$$K_2Mn_2O_8+5H_2C_2O_4+3H_2SO_4=K_2SO_4+2MnSO_4+8H_2O+10CO_2.$$

Calculation.—Subtract the volume of $\frac{n}{10}$ $H_2C_2O_4$ used from the volume of $\frac{n}{10}$ $KMnO_4$. The difference is the volume of $\frac{n}{10}$ $KMnO_4$ required by the amount of "unknown" titrated.

According to the first equation given, $Ca(PH_2O_2)_2$ has 8 hydrogen equivalents, since 5 molecules react with 4 molecules of $K_2Mn_2O_8$ having 40 hydrogen equivalents. Therefore, the molecular weight of $Ca(PH_2O_2)_2$ must be divided by 8 in figuring the $\frac{n}{10}$ factor. Calculate and report per cent of $Ca(PH_2O_2)_2$.

DETERMINATION OF H_2O_2 IN SOLUTION OF HYDROGEN PEROXIDE.

Process.—Weigh out about 10 Gm.; dilute to the mark on the flask; and take 1/5 for titration. Add 10 cc. of diluted H_2SO_4, and then just enough standard $KMnO_4$ solution to give the liquid a permanent pink tint.

$$5H_2O_2+K_2Mn_2O_8+3H_2SO_4=2MnSO_4+K_2SO_4+5O_2+8H_2O.$$

Of the ten atoms of oxygen evolved in the reaction five are yielded by the H_2O_2, and the other five by the $K_2Mn_2O_8$.

Calculation.—According to the equation, H_2O_2 has two hydrogen equivalents, since 5 molecules react with 1 molecule of $K_2Mn_2O_8$, which has 10 hydrogen equivalents. Calculate and report per cent of H_2O_2.

The strength of H_2O_2 solution may also be stated in volumes of available oxygen,—*i. e.*, by stating how many volumes of oxygen can be liberated from one volume of the H_2O_2 solution.* One molecule of $K_2Mn_2O_8$ liberates 5 atoms of O from the H_2O_2; hence 1 cc. of $\frac{n}{10}$ $KMnO_4$ solution indicates $\frac{O}{2}$, which equals $\frac{.0016}{2}$ or .0008 Gm. of O. Then .0008 Gm. multiplied by the number of cc. of $\frac{n}{10}$ $KMnO_4$ solution used, equals the weight of available O in the amount of "unknown" titrated. This can easily be converted into volume since the weight of a given volume of O is known, one cc. of O weighing approximately .00143 Gm. There will be as many cc. of O in the amount titrated, as .00143 is contained times in the number of grammes of O found. Calculate and report volumes of O yielded by this "unknown."

Example.—2 cc. of "unknown" required 40 cc. of $\frac{n}{10}$ $KMnO_4$. Find the volumes of available oxygen. .0008 Gm. × 40 = 0.032 Gm.,—

**Note.*—Some manufacturers incorrectly express the strength of their H_2O_2 solution by including the oxygen yielded by the $K_2Mn_2O_8$.

weight of O in 2 cc. Then .00143 Gm. (weight of 1 cc. of O) : .032 Gm. (weight of O found) :: 1 cc. : x. x=22.37 cc.,—the volume of O yielded by 2 cc. 22.37 cc.÷2=11.185 cc.,—the volume of O yielded by 1 cc. Therefore one volume of the H_2O_2 solution yields 11.185 volumes of oxygen.

Note.—The volume of a gas varies with atmospheric pressure and with temperature. (See Determination of $C_2H_5NO_2$, page 44.)

DETERMINATION OF $Na_2S_2O_3$ IN SODIUM THIOSULPHATE SOLUTION.

Process.—Weigh about 10 cc. and dilute to the mark on the flask. Take 1/10; add 3 drops of starch indicator (see United States Pharmacopoeia, page 480); and then run in $\frac{n}{10}$ Iodine from a glass stop-cocked burette, until a permanent blue color is obtained; showing a slight excess of iodine.

$$2Na_2S_2O_3+I_2=2NaI+Na_2S_4O_6 \text{ (Sodium tetrathionate).}$$

Calculation.—$Na_2S_2O_3$ is chemically equivalent to one atom ot H, as is shown by the above equation, Iodine having one hydrogen equivalent. Calculate and report per cent of $Na_2S_2O_3.5H_2O$.

DETERMINATION OF K_3AsO_3 IN POTASSIUM ARSENITE SOLUTION.

Process.—Weigh about 20 cc.: add 2 Gm. of chemically pure $NaHCO_3$; boil for a few minutes; cool; and dilute to the mark on the flask. Take 1/4 of the dilution and titrate against $\frac{n}{10}$ Iodine, using starch indicator.

$$K_3AsO_3+I_2+2NaHCO_3+H_2O=K_3AsO_4+2NaI+2CO_2+2H_2O.$$

Calculation.—Arsenous salts are chemically equivalent to two atoms of hydrogen, as may be seen from the given equation. Calculate and report per cent of K_3AsO_3.

Note.—Arsenous acid and arsenites should be titrated in the presence of an excess of a bicarbonate, added for the purpose of preventing the formation of free HI, which acts as a reducing agent, and would thus vitiate the result. The alkaline carbonates and hydroxides cannot be used to neutralize the HI, because they interfere with the proper working of starch indicator.

DETERMINATION OF Na_2SO_3 IN SODIUM SULPHITE SOLUTION.

Process.—Weigh about 10 cc.; dilute to the mark on the flask with recently boiled water; take 1/4; and titrate against $\frac{n}{10}$ Iodine, using starch solution as indicator.

$$Na_2SO_3+I_2+H_2O=2NaI+H_2SO_4.$$

Calculation.—According to the given equation, Na_2SO_3 is chemically equivalent to I_2, hence to H_2. Calculate and report per cent of $Na_2SO_3.7H_2O$.

Reduction.

Substances which have lost oxygen, or which have atoms in the molecule reduced from a higher to a lower quantivalence, are said to have undergone reduction. Of the many reducing agents, only three,—$Na_2S_2O_3$, Na_3AsO_3, and $H_2C_2O_4$,—are commonly used as volumetric solutions.

STANDARD SOLUTIONS.

DECINORMAL SOLUTION OF SODIUM THIOSULPHATE.

Process.—Weigh out 15 Gm. of the crystallized salt; dissolve; dilute to 500 cc.; and standardize against $\frac{n}{10}$ Iodine solution, using starch indicator. Make the calculation for the dilution, and dilute until 1 cc. exactly reduces 1 cc. of $\frac{n}{10}$ Iodine solution.

DECINORMAL SOLUTION OF SODIUM ARSENITE.

Process.—Dissolve 2.5 Gm. of pure As_2O_3 and 10 Gm. of $NaHCO_3$ in 200 cc. of water, using heat, if necessary, to effect solution. Dilute to 400 cc. and standardize against $\frac{n}{10}$ Iodine solution, using starch as indicator.

Note.—The solution contains excess of $NaHCO_3$ to prevent the formation of HI in the Iodine titration.

DETERMINATIONS.

DETERMINATION OF I IN TINCTURE OF IODINE.

Process.—Weigh about 10 cc. in a closed flask; add 10 cc. of 15% KI solution, which prevents precipitation on diluting with water; and dilute to the mark on the flask. Take 1/10 for titration. Run in $\frac{n}{10}$ $Na_2S_2O_3$ solution until the brown color is almost discharged; then add 3 drops of starch indicator; and continue the addition of $Na_2S_2O_3$ solution until the blue color has just disappeared.

$$2Na_2S_2O_3+I_2=2NaI+Na_2S_4O_6.$$

Calculation.—Report per cent of I.

DETERMINATION OF AVAILABLE Cl IN BLEACHING POWDER.

Principle.—The value of chlorinated lime depends not upon the total amount of Cl it contains, but upon the amount available for oxidizing purposes,—namely, all Cl existing as hypochlorite, plus an equal amount existing as chloride. The available chlorine, in the presence of an acid, will liberate its chemical equivalent of iodine from KI, of which an excess must be present. This liberated iodine requires just as much $\frac{n}{10}Na_2S_2O_3$ for reduction, as the available chlorine which liberated it would, could it be titrated against $Na_2S_2O_3$ directly.

Process.—Weigh out about one gramme, and triturate in a clean mortar with 10 cc. of water to a smooth paste. Then add 50 cc. more of water and pour the milky liquid into a graduated cylinder. Rinse the mortar with several portions of water, adding the washings to the liquid in the cylinder, and finally dilute to a convenient volume (200 cc.). Shake the liquid vigorously, and while yet homogeneous, divide into two parts. To one of these, add 1.5 Gm. of KI and 8 cc. of diluted HCl.

$$Ca(ClO)_2.CaCl_2+4HCl=2Cl_2+2CaCl_2+2H_2O.$$
$$Cl_2+2KI=2KCl+I_2.$$

Then, having shaken or stirred the liquid, run in $\frac{n}{10}Na_2S_2O_3$ solution until all free I has been reduced, using starch indicator towards the end of the reaction.

$$I_2+2Na_2S_2O_3=2NaI+Na_2S_4O_6.$$

Use the other half of the dilution for a duplicate titration.

Calculation.—This is based upon the factor for Cl and the amount of $\frac{n}{10}Na_2S_2O_3$ used, it being unnecessary to take into account the I. Calculate and report per cent of Cl.

Note.—In case the bleaching powder contains $Ca(ClO_3)_2$, the preceding process gives erroneous results, indicating not only the available chlorine, but also the chlorine of the $Ca(ClO_3)_2$, which is not available for oxidizing purposes. For such samples, the process given below must be used.

Process.—To one-half of the dilution, prepared just as in the preceding process, add a measured excess (80 cc.) of $\frac{n}{10}$ Na_3AsO_3 solution and mix well.

$$CaCl_2.Ca(ClO)_2+2Na_3AsO_3=2CaCl_2+2Na_3AsO_4.$$

Then titrate back with $\frac{n}{10}$ I solution, using starch as indicator.

$$Na_3AsO_3+I_2+2\ NaHCO_3+H_2O=Na_3AsO_4+2NaI+2CO_2+2H_2O.$$

Calculation.—The volume of Na_3AsO_3 solution minus the volume of I solution is the volume of Na_3AsO_3 solution required by the available chlorine present in the amount of "unknown" titrated. Calculate and report per cent of Cl.

DETERMINATION OF $FeCl_3$ IN SOLUTION OF FERRIC CHLORIDE.

Principle.—Ferric salts, being reducible, are capable of oxidizing other substances. Thus, $FeCl_3$ is capable of oxidizing HI (KI in the presence of a mineral acid), in which reaction free iodine results. If KI and mineral acid be present in excess, the amount of I liberated depends wholly upon the amount of $FeCl_3$ present.

Process.—Weigh out about 1.5 Gm. of the solution and transfer to a 100 cc. glass stoppered bottle, rinsing the weighing flask with several successive portions of water, so as to avoid loss in the transfer. Dilute to about 20 cc.; add 2 cc. of HCl and 1 Gm. of KI; and mix well. Stopper tightly and keep at a temperature of about 40°C. for 30 minutes.

$$2FeCl_3+2KI=2FeCl_2+2KCl+I_2.$$

Then cool, and determine the liberated I by titration against $\frac{n}{10}$ $Na_2S_2O_3$ solution, using starch solution as indicator.

$$I_2+2Na_2S_2O_3=2NaI+Na_2S_4O_6.$$

Calculation.—This may be deduced from the given equations. Calculate and report per cent of $FeCl_3$.

DETERMINATION OF Fe IN A SCALE SALT OF IRON.

Process.—Weigh out about 5 Gm.; transfer to a 100 cc. glass-stoppered bottle; add 20 cc. of water and 2 cc. of HCl and heat gently until a clear solution is formed. Then add 1 Gm. of KI; mix well; stopper tightly; and warm to 40° C., maintaining this temperature for 30 minutes. Then cool, and determine the liberated I by titration against $\frac{N}{10}$ $Na_2S_2O_3$ solution, using starch indicator. The equations are the same as in the preceding exercise.

Calculation.—This is similar to that for the preceding exercise. Calculate and report per cent of Fe.

DETERMINATION OF C_6H_5OH IN SOLUTION OF PHENOL.

Process.—Weigh out accurately about 1.5 Gm. of the "unknown." Then proceed as directed in the official method on page 10 of the United States Pharmacopoeia.

Explanation.—The first step in the process consists in adding a measured excess of standard Bromine solution. The bromine unites with the phenol to form tri-brom-phenol, which precipitates out.

$$C_6H_5OH+3Br_2=C_6H_2Br_3OH+3HBr.$$

The excess of Br is then determined by causing it to liberate its equivalent of I from KI, and titrating the freed I against standard $Na_2S_2O_3$ solution.

$$Br_2+2KI=2KBr+I_2.$$
$$I_2+2Na_2S_2O_3=2NaI+Na_2S_4O_6.$$

Bromine cannot readily be titrated directly, but this indirect method is as accurate as a direct method could be, for the I liberated by the excess of Br, requires just as much $Na_2S_2O_3$, as the Br itself would require, could it be titrated directly.

Calculation.—Subtract the amount of $Na_2S_2O_3$ solution used from the amount of Br solution used. The difference is the amount of Br solution required by the amount of "unknown" titrated. C_6H_5OH has 6 hydrogen equivalents (see equation above), and in figuring its $\frac{N}{10}$ factor, the molecular weight must therefore be divided by 6. Calculate per cent of C_6H_5OH in the usual way and report.

Note.—The official Br solution contains no free Br, but is a solution of $KBrO_3$ and KBr, which, on the addition of hydrochloric acid, yields free Br. This official solution has the advantage of permanency, whereas simple Br solution loses strength rapidly.

ANALYSIS BY PRECIPITATION.

In analysis by precipitation, the methods are based upon the same principles as the methods already described, the only characteristic being the formation of a precipitate. In neutralization, the volumetric solutions are acids or alkalies; in oxidation and reduction they are oxidizing or reducing agents; and in precipitation they are precipitants.

STANDARD SOLUTIONS.

DECINORMAL SOLUTION OF SILVER NITRATE.

Process.—Weigh out 4.239 Gm. of pure crystallized silver nitrate, dissolve, and dilute to exactly 250 cc.

DECINORMAL SOLUTION OF SODIUM CHLORIDE.

Process.—Dissolve about 3 Gm. of sodium chloride in 400 cc. of water and standardize against $\frac{n}{10}$ $AgNO_3$, conducting the titration as follows:—To 10 cc. of the solution, add 3 drops of potassium chromate T. S. (see United States Pharmacopoeia, page 477), and then $\frac{n}{10}AgNO_3$ solution from a burette until a permanent reddish-brown color tinges the precipitate.

$$AgNO_3+NaCl=AgCl+NaNO_3.$$

$$2AgNO_3+K_2CrO_4=Ag_2CrO_4+2KNO_3.$$

The $AgNO_3$ first reacts with the sodium chloride; and when the latter has all been converted into the silver salt, the $AgNO_3$ reacts with the K_2CrO_4, forming Ag_2CrO_4, a red, insoluble compound. The appearance of a red color therefore indicates the complete precipitation of the chloride.

Note.—K_2CrO_4 cannot be used as an indicator in the presence of iron; nor can it be used when HNO_3 is present or is evolved from the $AgNO_3$ in the reaction, since Ag_2CrO_4 is soluble in HNO_3.

DECINORMAL SOLUTION OF POTASSIUM SULPHOCYANATE.

Process.—Dissolve 5 Gm. of potassium sulphocyanate in 500 cc. of water, and standardize against $\frac{n}{10}$ $AgNO_3$ as follows:

To 10 cc. of $\frac{n}{10}$ $AgNO_3$ solution add 5 cc. of ferric ammonium sulphate T. S. (see United States Pharmacopoeia, page 470) and

5 cc. of dilute nitric acid. Then run in KSCN solution from a burette until a reddish-brown color appears, indicating that all $AgNO_3$ has been changed to the sulphocyanate. The KSCN first reacts with the $AgNO_3$, and when all of this has been consumed, it next reacts with the ferric salt, forming red ferric sulphocyanate.

$$KSCN+AgNO_3=AgSCN+KNO_3.$$

$$6KSCN+Fe_2(NH_4)_2(SO_4)_4=Fe_2(SCN)_6+(NH_4)_2SO_4+3K_2SO_4.$$

Then dilute the KSCN solution so that 1 cc. will exactly precipitate out the silver from 1 cc. of $\frac{n}{10}$ $AgNO_3$ solution.

DETERMINATIONS.

DETERMINATION OF NaCl IN SOLUTION OF SODIUM CHLORIDE.

Process.—Weigh out about 1 Gm. and dilute to the mark on the flask. Take 1/10 and titrate against $\frac{n}{10}$ $AgNO_3$ solution as directed under Decinormal Solution of Sodium Chloride, page 41.

Calculation.—According to the given equation (see page 41), NaCl is equivalent to one hydrogen atom. Calculate in the usual way, and report per cent of NaCl.

DETERMINATION OF HCN IN SOLUTION OF HYDROCYANIC ACID.

Process.—Weigh about 5 cc. and dilute to the mark on the flask. Take 1/10 for the titration, which should be conducted as follows:

Add magnesia (MgO) in excess, *i. e.*, until a turbid mixture results.

$$MgO+2HCN=Mg(CN)_2+H_2O.$$

To this add 3 drops of K_2CrO_4 solution, and then $\frac{n}{10}$ $AgNO_3$ solution from a burette until the precipitate is tinged a flesh color, due to a trace of Ag_2CrO_4.

$$Mg(CN)_2+2AgNO_3=2AgCN+Mg(NO_3)_2.$$

The $AgNO_3$ reacts first with the cyanide; and the appearance of the Ag_2CrO_4 shows that all cyanide has been precipitated as AgCN.

Note.—The MgO is added to prevent the formation of free HNO_3 during the titration, the HNO_3 interfering with the K_2CrO_4 indicator, and also with the formation of AgCN. Moreover, the MgO prevents the volatilization of HCN during titration.

Calculation.—HCN is equivalent to one hydrogen atom. Calculate and report per cent of HCN.

DETERMINATION OF KCN IN SOLUTION OF POTASSIUM CYANIDE.

Process.—Weigh about 5 cc. and dilute to the mark on the flask. Take 1/10 for titration, and add $\frac{n}{10}$ $AgNO_3$ until a *permanent* turbidity results.

$$2KCN + AgNO_3 = KCN.AgCN + KNO_3.$$
$$KCN.AgCN + AgNO_3 = 2AgCN + KNO_3.$$

In this titration, a double cyanide, KCN.AgCN, is first formed; then, on adding $AgNO_3$ in excess over the amount required for the conversion of all KCN into KCN.AgCN, insoluble AgCN forms and causes a turbidity. The appearance of a cloudiness therefore shows that enough (and a little more) $AgNO_3$ has been added to convert all the KCN into KCN.AgCN.

Calculation.—The given equation shows that in calculating the factor for KCN, the molecular weight of the latter must be *multiplied* by two. Calculate and report per cent of KCN.

Note.—This titration can also be conducted to the point where all KCN has been converted into AgCN, as shown in the second equation given above. K_2CrO_4 is used to indicate the end reaction in such titrations.

DETERMINATION OF FeI_2 IN SYRUP OF FERROUS IODIDE.

Process.—Weigh about 8 cc. and dilute to the mark on the flask. Take 1/5 for the titration, which should be conducted as follows:

First add a measured excess (20 cc.) of $\frac{n}{10}$ $AgNO_3$ solution.

$$2AgNO_3 + FeI_2 = 2AgI + Fe(NO_3)_2.$$

Then add 5 cc. of dilute HNO_3 and 5 cc. of ferric ammonium sulphate T. S. as indicator, and finally run in $\frac{n}{10}$ KSCN from a burette until a reddish color is obtained, which does not disappear on shaking.

$$AgNO_3+KSCN=AgSCN+KNO_3.$$

When all $AgNO_3$ has been consumed, the least excess of the KSCN becomes noticeable on account of its reaction with the indicator, with which it forms a red compound according to the following equation:

$$Fe_2(NH_4)_2(SO_4)_4+6KSCN=Fe_2(SCN)_6+(NH_4)_2SO_4 \\ +3K_2SO_4.$$

Calculation.—From the volume of $\frac{n}{10}$ $AgNO_3$, added to the "unknown," deduct the volume of $\frac{n}{10}$ KSCN used in the residual titration. The remainder is the volume of $\frac{n}{10}$ $AgNO_3$ required for the amount of "unknown" titrated. FeI_2 is chemically equivalent to 2 atoms of hydrogen. Calculate and report per cent of FeI_2.

GASOMETRIC ANALYSIS.

In gasometric methods, the substance estimated is decomposed so as to yield a gas, which is measured. From the volume of gas yielded, the amount of substance may be calculated. Gasometric methods may be employed in the determination of ethyl nitrite, amyl nitrite, hydrogen peroxide, bleaching powder, manganese dioxide, carbonates, etc. Gases which are quite soluble in water, as for instance CO_2, Cl, and O, are measured over mercury; while such as are practically insoluble, as for example, N and NO, may be measured over water. In the assay of ethyl nitrite and in other similar assays, to further reduce the solvent action of water, and also to increase its specific gravity so that the "unknown" will not readily diffuse, but will stay at the top, the water is saturated with sodium chloride.

An apparatus used for measuring gases is called a gasometer; a gasometer for N or NO is called a nitrometer.

DETERMINATION OF $C_2H_5NO_2$ IN SPIRIT OF NITROUS ETHER.

Principle.—The official process for assaying spirit of nitrous ether consists in decomposing the ethyl nitrite by means of KI and H_2SO_4, and measuring the nitric oxide, NO, evolved. From the volume of NO evolved, the amount of ethyl nitrite is calculated.

Apparatus.—A nitrometer may be improvised as follows:

Measure the ungraduated space, from the 50 cc. mark to the stop-cock, of an "acid" burette. Attach to the delivery tube of the burette, a small funnel by means of a short rubber tube. Close the top of the burette with a perforated cork, through the perforation of which a short (1½ inch) glass tube has been inserted. To this glass tube attach a rubber tube (two feet in length), the other end of which has previously been attached to the stem of a small percolator. Fasten the burette in a perpendicular position, top downward; and support the percolator, right side up, on a ring fastened to the same ring-stand to which the burette is clamped.

Process.—Fill the percolator to within two inches of the top with a saturated solution of sodium chloride. Open the stop-cock of the burette, raise the percolator, and allow the salt solution to pass over into the burette, until it has entirely filled the same, including the delivery tube above the stop-cock. Next close the stop-cock, and lower the percolator.

Pour a weighed quantity (about 5 Gm.) of the "unknown" into the small funnel attached to the delivery tube. Open the stopcock and allow the "unknown" to run into the burette, taking care that no air enters at the same time. Next introduce into the burette in the same manner, 10 cc. of potassium iodide T. S. and 10 cc. of 5% sulphuric acid. To prevent the ingress of air, 20 cc. of 5% sulphuric acid should be put into the funnel, and only one-half of the whole amount be allowed to run into the burette. As soon as the sulphuric acid has been added, reaction will take place according to the following equation:

$$2C_2H_5NO_2+2KI+2H_2SO_4=2NO+I_2+2C_2H_5OH+2KHSO_4.$$

The iodine, alcohol, and potassium acid sulphate dissolve in the salt solution; but the NO, which is a gas, and is insoluble in aqueous liquids, forces the brine down and over into the percolator, and occupies the upper space in the inverted burette. If the burette be shaken at intervals, the reaction will be complete at the end of 10 minutes. Then raise or lower the percolator until the level of the liquid in the same coincides with the level of the liquid in the burette. The pressure to which the NO is subjected will then be identical with the atmospheric pressure. Now take the reading of the volume of gas, noting at the same time the barometric pressure and the temperature of the atmosphere near the nitrometer.

Calculation.—The volume of a certain quantity of a gas depends 1st, upon the pressure to which it is subjected, and, 2nd, upon the temperature. Boyle's law states that the volume of a gas varies inversely as the pressure; thus, if we double the pressure on a certain amount of a gas, we reduce its volume to one-half. The standard of pressure taken for the measurement of gases is equal to that of a column of mercury 760 mm. in height. If our barometer reads 748 mm. at the time the reading of the volume of gas is taken, the volume will be too large, and a correction must be made. Suppose the reading of gas to be 55.88 cc. at a pressure of 748 mm. Then at 760 mm., the reading will be $\frac{748}{760}\times 55.88$ cc., or 55 cc.

The normal temperature for the measurement of gases is 0°C., and since our reading was taken at a temperature many degrees higher than 0°C., correction must be made for the expansion of the gas at this increased temperature. This is accomplished by applying Charles' law, which states that the volume of a gas varies directly as the temperature measured from the absolute zero —273°C. For example, suppose the gas measured 55 cc. at 25°C., but the volume of gas at 0°C. is required. Then:

(1.) (273°+25°):(273°+0°)::55 cc. (volume of gas at 25°C.) : x (volume of gas at 0°C.). x=50.4 cc.

(2.) One cc. of NO at 0°C. weighs .001344 Gm. In 50.4 cc. there will therefore be 50.4 ×.001344 Gm., or .0677376 Gm. of NO.

(3.) From the weight of NO evolved, the weight of ethyl nitrite in the amount of "unknown" operated on is calculated as follows:

Molecular weight of NO (29.97): molecular weight of $C_2H_5NO_2$ (74.88)::weight of NO evolved (.0677376 Gm.): weight of $C_2H_5NO_2$ in amount of "unknown" operated on (.1692423 Gm.).

(4.) From the weight of $C_2H_5NO_2$, the percentage strength is calculated in the usual way:—Amount of "unknown" taken (4.2 Gm.): .1692423 Gm.::100:x. x=4.029%.

SPECIFIC GRAVITY.

Density is the relation which the weight of a body bears to the space it occupies. Relative density, or specific gravity, is the relation which the density of one body bears to the density of another body, taken as a standard of density. For liquids and solids, the density of pure water, at 15°C., is taken as the standard, and is expressed by unity,—by 1.000. [This is the standard adopted by the United States Pharmacopoeia. Physicists, however, take for their standard, pure water at the temperature at which it has its greatest density, namely 4°C.] For gases, hydrogen at 0°C. is taken as the standard of density. The numerical expression by which specific gravity is stated indicates how many times as light or as heavy, a certain volume of the substance is, as is the same volume of water. The numerical expression may consist of a whole number, a decimal fraction, or a mixed decimal fraction. Interminate fractions are usually carried to the third place; thus, 1:333.

DETERMINATIONS.

1. LIQUID.

Process.—Completely fill a clean, dry, tared specific-gravity bottle (pyknometer) with distilled water at 15°C. Weigh accurately. Dry the bottle, fill it with the liquid (at 15°C.), the specific gravity of which is to be determined, and again weigh. In each case subtract the weight of the bottle. Then divide the weight of the liquid by the weight of the water. The answer is the specific gravity of the liquid. [The weight of water which the pyknometer holds at 15°C. should be recorded for future use.]

Example.—When filled with pure water at 15°C., the pyknometer weighs 28.84 Gm. When filled with glycerin at 15°C., it weighs 32.65 Gm. Alone, it weighs 13.6 Gm. Find the specific gravity of the glycerin.

Weight of Pyknometer+Water	28.84 Gm.
" " " alone	13.60 "
" " Water "	15.24 Gm.

Weight of Pyknometer+Glycerin	32.65 Gm.
" " " alone	13.60 "
" " Glycerin "	19.05 Gm.

$\frac{\text{Weight of Glycerin}}{\text{Weight of Water}} = \frac{19.05}{15.24} = 1.25$,—specific gravity of Glycerin.

2. SOLID, GRANULAR OR POWDERED, INSOLUBLE IN WATER AND HEAVIER THAN THE SAME.

Process.—Put a convenient quantity of the substance (about 5 Gm.) into a dry pyknometer, the tare of which has previously been ascertained. Weigh accurately. Then pour about 10 cc. of pure distilled water upon the substance, and shake well in order to thoroughly moisten the same. Finally add enough water at 15°C. to completely fill the bottle, and again weigh. Then calculate as follows:

a. From the total weight of pyknometer, substance, and supernatant liquid (water), deduct the weight of the pyknometer and substance. The remainder is the weight of the supernatant water.

b. Subtract the weight of the supernatant water from the weight of water at 15°C., which the bottle will hold when completely filled with it (determined in exercise 1). The remainder is the weight of water displaced by the substance; hence, the weight of an *equal volume* of water.

c. Finally divide the weight of the substance taken, by the weight of the water displaced by the substance. The answer is the specific gravity of the solid.

Example.—The weight of pyknometer and substance (reduced iron) is 18. Gm. The total weight of bottle, reduced iron, and supernatant water is 32.629 Gm. Find the specific gravity of the reduced iron.

Weight of Pyknometer+Reduced Iron	18.0 Gm.
" " " alone	13.6 "
" " Reduced Iron alone	4.4 Gm.

Weight of Pyknometer+Iron+Supernatant Water	32.629 Gm.
" " " + "	18.000 "
" " Supernatant Water alone	14.629 Gm.

Weight of Water held by Pyknom. (see exercise 1)	15.240 Gm.
" " Supernatant Water	14.629 "
" " Water displaced, or an Equal Vol. of Water	.611 Gm.

$$\frac{\text{Weight of Reduced Iron}}{\text{Weight of Displaced Water}} = \frac{4.4}{.611} = 7.201,\text{—}$$

specific gravity of the Reduced Iron.

3. Solid in Mass, Heavier Than Water and Insoluble in the Same.

Principle.—A body immersed in a fluid loses in weight as much as the displaced fluid weighs. A cubic inch of water weighs 252.+grains. One cubic inch of a solid, when weighed suspended in water, weighs 252.+grains less than when weighed in air. Since this loss in weight represents the weight of an equal volume of water, we can determine the specific gravity by dividing the weight of a substance (in air) by its loss in weight when weighed in water.

Process.—By means of a tared horse-hair, suspend the solid from the balance arm in such a manner that the solid hangs about 2½ inches above the balance pan. Weigh. Then weigh the solid suspended in a beaker of water which has been cooled or warmed to 15°C. The beaker is to be supported by a bench which straddles and does not touch the balance pan.

Calculation.—Subtract the weight of the solid in water from its weight in air. The difference is the weight of the water displaced, *i. e.*, the weight of the same volume of water. Then divide the weight of the solid in air by the weight of the water displaced. The answer is the specific gravity of the solid.

Example.—After deducting the weight of the horse-hair, the solid (Roll Sulphur) in air weighs 6.840 Gm.; and in water at 15°C., 3.614 Gm. Find the specific gravity of the Roll Sulphur.

Weight of Roll Sulphur in air....................6.840 Gm.
" " " " " water..................3.614 "

Loss in Weight, or Weight of Equal Volume of Water 3.226 Gm.

$$\frac{\text{Weight of Roll Sulphur in air}}{\text{Weight of Equal Volume of Water}} = \frac{6.840}{3.226} = 2.120, \text{—specific gravity of the Roll Sulphur.}$$

4. Solid in Mass, Insoluble in Water, and Lighter Than the Same.

Principle.—When a substance is lighter than water, and capable of floating, a heavy substance must be used as a "sinker;" for in order to determine the specific gravity, the substance must be sunk below the surface of the liquid, so that an equal volume of the latter is displaced.

Process.—(a.) Weigh the solid in air. (b.) Determine the weight in air of a piece of lead to be used as a sinker. (c.) Tie both solid and sinker (the latter below) to a tared horse-hair. Attach the other end of the horse-hair to the balance arm, and weigh the solid and sinker in water at 15°C. (See exercise 3). (d.) Detach the solid from the horse-hair, and weigh the sinker in water by itself.

Calculation.—(a.) Subtract the weight of sinker in water from the weight of sinker in air. The difference is the weight of water displaced by sinker. (b.) From the total weight of solid and sinker in air, deduct the total weight of solid and sinker in water. The difference is the weight of water displaced by solid and sinker. (c.) From the weight of water displaced by solid and sinker, deduct the weight of water displayed by sinker. The difference is the weight of water displaced by the solid. (d.) Finally divide the weight of solid in air by the weight of water displaced by the solid. The answer is the specific gravity of the solid.

Example.—A piece of paraffin in air weighs 2.895 Gm. Attached to a sinker, after deducting the weight of the horse-hair, it weighs 14.086 Gm. The sinker and paraffin in water at 15°C. together weigh 8.258 Gm., while the sinker by itself in water weighs 8.652 Gm. Find the specific gravity of the paraffin.

Weight of Paraffin + Sinker in air	14.086	Gm.
" " " in air	2.895	"
" " Sinker in air	11.191	Gm.
" " " " water	8.652	"
" " Water displaced by Sinker	2.539	Gm.

Weight of Paraffin + Sinker in air	14.086	Gm.
" " " + " " water	8.258	"
" " Water displaced by Paraffin+Sinker	5.828	Gm.
" " " " " Sinker	2.539	"
" " " " " Paraffin	3.289	Gm.

$$\frac{\text{Weight of Paraffin in air}}{\text{Weight of Water displaced by Paraffin}} = \frac{2.895}{3.289} = .880, \text{– specific gravity of Paraffin.}$$

SOLID IN MASS, SOLUBLE IN WATER.

Process.—Proceed as directed in exercise 3 (page 49); but instead of weighing in water, weigh in oil of turpentine at 15°C., in which the substance is insoluble. Then determine the specific gravity of the oil of turpentine by means of a specific gravity bottle (see exercise 1).

Calculation.—Divide the weight of substance in air, by its loss in weight when weighed in oil of turpentine. This gives the specific gravity of the substance, referred to oil of turpentine. Calculate to specific gravity referred to water (the standard of density) by multiplying by the specific gravity of the oil of turpentine used.

$\frac{\text{Weight of Substance}}{\text{Weight of Turpentine}}$ = specific gravity of Substance referred to Oil of Turpentine.

$\frac{\text{Weight of Turpentine}}{\text{Weight of Water}}$ = specific gravity of Oil of Turpentine, referred to Water.

Then, specific gravity of substance referred to oil of turpentine, multiplied by specific gravity of oil of turpentine referred to water =

$\frac{\text{Weight of Substance}}{\text{Weight of Turpentine}} \times \frac{\text{Weight of Turpentine}}{\text{Weight of Water}} = \frac{\text{Weight of Substance}}{\text{Weight of Water}} =$ specific gravity of substance referred to water.

Example.—A crystal of alum, weighing 3.824 Gm. in air, weighs 1.901 Gm. when weighed in oil of turpentine. The specific gravity of the oil of turpentine is found to be .860. Find the specific gravity of the alum.

Weight of Alum in air	3.824 Gm.
" " " " oil of turpentine	1.901 "
" " Turpentine displaced by Alum	1.923 Gm.

$\frac{\text{Weight of Alum in air}}{\text{Weight of Turpentine displaced by Alum}} = \frac{3.824}{1.923} = 1.988$,—specific gravity of Alum referred to oil of turpentine.

1.988 × .860 (specific gravity of turpentine) = 1.709,—the true specific gravity of the Alum.

6. SOLID OR SEMI-SOLID, INSOLUBLE IN WATER AND ALCOHOL.

Principle.—A body will sink in a liquid of a lower specific gravity than its own; in a liquid of higher specific gravity it will float, only partially immersed; and in a liquid of the same specific gravity, it will float about indifferently, neither sinking to the bottom of the vessel nor rising to the surface of the liquid.

Process.—Drop a particle of the substance into water. Should the substance float, transfer it to alcohol in which it will sink. Then add water to the alcohol until the substance floats indifferently. Should the substance, however, sink in water, transfer it to a saturated solution of sodium chloride in which it will float, and then add water to the salt solution until the substance sinks below the surface, and floats wholly immersed. Finally take the specific gravity of the liquid (see exercise 1). The substance will have the same specific gravity.

Note.—These determinations must be made at 15°C. Other liquids of different densities may be employed, provided that they exert no solvent action on the substance.

7. LIQUID. SPECIFIC GRAVITY TO BE DETERMINED BY MEANS OF A HYDROMETER.

Principle.—Hydrometers are instruments for the measurement of specific gravity, their use depending upon the fact that they will sink in a liquid until the part immersed has displaced an amount of water equal in weight to that of the whole hydrometer. They consist of a long graduated tube, having two bulbs at the lower end, the one to enable it to float, and the other weighted with shot or mercury to make it float in an upright position. The tube is either graduated so that the specific gravity of the liquid in which it floats may be read off the scale directly, or it is graduated empirically, when the specific gravity may be calculated from the readings, as in case of Baumé's hydrometers. [For liquids lighter than water, the following formula is used in changing from degrees Baumé, to the ordinary expression of specific gravity:

$$\frac{144.3}{134.3+B}=\text{specific gravity.}$$

For liquids heavier than water, the following calculation is made:

$$\frac{144.3}{144.3-B}=\text{specific gravity.}$$

In either case, B means the reading on the Baumé hydrometer, the liquid having been at 15°C.] There are also hydrometers of constant immersion, with which it is necessary to use weights in order to immerse always to the same mark.

Note.—Specific gravity beads are small balloon-shaped glass bodies of known specific gravity. In liquids of the same specific gravity as their own, they float about indifferently; in lighter liquids they sink to the bottom of the container; and in heavier liquids, they float at the surface, partially immersed. They are especially convenient in evaporating to a certain specific gravity; also in obtaining distillates of certain densities.

8. LIQUID. SPECIFIC GRAVITY TO BE DETERMINED BY MEANS OF A WESTPHAL'S BALANCE.

Principle.—Westphal's specific gravity balance is constructed on the principle that the losses in weight of a body when weighed in different liquids are proportional to the weights of the same volume of the liquids displaced; hence, proportional to their specific gravities. Such a body, consisting of a small glass thermometer, is suspended from a hook at the end of one arm of a small balance, and is counterpoised by an equal weight on the other arm, a pointer showing the balance to be in equilibrium. The thermometer, while still connected to the arm of the balance, is then weighed in water, and a weight W, equal to the loss in weight of the thermometer, is suspended from the same hook. The equilibrium is thus restored. Weights of $\frac{1}{10}$, $\frac{1}{100}$, and $\frac{1}{1000}$ of the weight of W are provided. To determine the specific gravity of a liquid, the thermometer is suspended in the liquid at 15°C., from the arm of the balance, and its loss in weight is measured directly by the weights necessary to restore the equilibrium to the balance. If W, representing the thermometer's loss in weight in water, be called 1.000, the reading will be the specific gravity of the liquid.

Specific Volume.

Specific volume is the relation which the volume of one body bears to the volume of the same weight of another body, taken as a standard of density. It is the exact reciprocal of specific gravity, and is merely a different expression of the same fact. The greater the specific gravity of a liquid, the smaller is its specific volume, and *vice versa.*

$$\frac{1.000}{\text{Specific Gravity}} = \text{Specific Volume.}$$

DETERMINATION OF BOILING POINT.

The boiling point of a liquid is the temperature of the vapor evolved from the boiling liquid. The temperature of the vapor evolved is influenced only by air pressure; while the temperature of the boiling liquid varies with the nature of the containing vessel, the amount of air or gases held in solution, or solids held in suspension.

Process.—Fill a 200 cc. distilling flask ⅔ full of the liquid. Fit the flask accurately with a stopper, through a perforation in which insert a thermometer in such a way that the bulb comes just below the exit of the outlet tube, but is not immersed in the liquid during boiling. Connect the distilling flask with a condenser and apply heat, very slowly at first, gradually increasing the heat until the liquid boils vigorously. Then, when the mercury in the thermometer ceases to rise and remains constant, take the reading.

DETERMINATION OF MELTING POINT.

Process. – Carefully heat a piece of soft glass-tubing in a Bunsen flame until it may be drawn out into a fine capillary tube. Cool the tube, break it in the center of the finely drawn out part, and fuse shut the pointed ends. Introduce into one of the tubes a small quantity of the finely powdered substance, the melting point of which is to be determined, having previously thoroughly dried the substance in an air-bath at 105°C., or in a desiccator over sulphuric acid. Cause the powder to collect to a depth of half an inch in the capillary tube, by carefully shaking or tapping the same. Fasten the tube to a thermometer, with the point containing the powder opposite the bulb, by means of a rubber band. Insert the upper end of the thermometer through a cork provided with two perforations, the second one being merely an outlet, and insert the cork in a small flask filled ⅔ full of pure, concentrated sulphuric acid, so that the thermometer bulb and capillary tube come within ½ inch of the bottom. Place the flask upon a wire gauze and heat by means of a Bunsen flame, slowly at first and gradually increasing the temperature, until the powder in the tube is seen to contract suddenly, and to melt. Note the exact temperature at which this takes place. If the substance does not melt suddenly, but fuses slowly through a range of several degrees of temperature, carefully note the point at which the substance begins to fuse and the point at which the melting is completed. Gradual melting usually denotes that the substance under examination contains impurities of varying melting points, or is a mixture, and not a simple chemical substance. By attaching two capillary tubes to the thermometer, two determinations can be made at one operation.

DETERMINATION OF SOLUBILITY.

The solubility of a substance in water is determined by making a saturated aqueous solution of the substance at the temperature at which the solubility is desired to be known, and then evaporating to dryness a weighed quantity of this saturated solution and weighing the residue. From these weights, the solubility is calculated. In order to make a saturated solution, either an excess of the substance may be kept in contact with water at the proper temperature until a saturated solution is obtained; or a quantity of the substance may be treated with water at a higher temperature than that at which its solubility is to be determined, and the saturated solution at the higher temperature be allowed to cool until the proper temperature is reached. Then, after filtering, a weighed quantity of the filtrate is ready to be evaporated to dryness.

Process for "Unknown."—Take 10 or 20 Gm. of the substance, and add water slowly until about one-half of the solid is dissolved. Keep at a temperature of 15°C. for one hour, agitating well every 10 minutes. Then filter through a dry (not moistened), plaited, double filter, held in a perfectly dry funnel, which should be at as nearly 15°C. as possible. Reject the first few cc. of filtrate; then collect about one-half of the entire amount of filtrate in a tared beaker, and weigh. Evaporate to apparent dryness on a water-bath; transfer to an air-bath, and keep at 105°C. until constant weight is obtained.

Calculation.—The difference between weight of residue and weight of solution taken is the weight of solvent required. Then, weight of residue:weight of solvent::1:x. x=parts by weight of solvent required to dissolve 1 part of substance.

Notes.—(1.) Results by this process are sufficiently accurate for ordinary purposes.

(2.) In case of non-volatile solvents, or very volatile solvents, as also in case of very soluble or very difficultly soluble substances, the preceding process is not applicable without modification.

VALUATION OF DRUGS and PREPARATIONS.

[PHARMACEUTICAL ASSAYING.]

By this is understood the determination, in a drug or in a medicinal preparation, of the constituent or constituents to which is due the medicinal activity.

In order to establish the dosage of drugs and galenical preparations upon a scientific basis, it is necessary to have for them a fixed and recognized standard of strength. Making the preparations to represent a given amount of drug does not insure uniformity of strength, owing to the variability in strength of the drug itself. Thus, Cinchona varies in alkaloidal strength from less than 1% to 12%; crude Opium may contain from 2% to 13% of Morphine. As the medicinal strength of drugs varies directly with the active constituents, the dose should vary inversely with the active constituents; or, better still, the drug or preparation should, when possible, be *standardized*, *i. e.*, brought to a fixed standard of strength - a fixed per cent of active constituents. Unfortunately, an accurate determination of medicinal constituents is thus far possible with but a limited number of drugs,—notably with those containing alkaloids as active constituents. An additional few (Digitalis, Indian Cannabis, Ergot, Strophanthus, etc.) may be roughly standardized by physiological experiments on lower animals.

Note.— **Fairly accurate chemical assays are known for such non-alkaloidal drugs as Wild Cherry, Podophyllum; Rhubarb, Elaterium, Cantharides, and Mustard; also for the digestive ferments.**

ALKALOIDAL DETERMINATIONS.

General Remarks.

Most assay processes for alkaloidal drugs consist of three distinct steps:—(1) the extraction or exhaustion of the drug; (2) the isolation of the alkaloids from the other plant principles simultaneously extracted; (3) the final determination,—either by weighing or volumetrically.

EXHAUSTION OF THE DRUG.

In selecting the extrating fluid, the following requisites must be kept in view:—(1) the solvent should have the power of readily penetrating the cell walls of the drug; (2) it should be a good solvent for the respective alkaloids; (3) it should not extract from the drug, principles which cannot be removed by subsequent operations,—this being specially important if the alkaloids are to be determined gravimetrically.

Generally speaking, salts of alkaloids are almost insoluble in etherial solvents (ether, petroleum ether, chloroform, etc.); while the free alkaloids are readily soluble therein. Since most alkaloids exist in the drug, not in the free state, but as salts, etherial menstrua are used always in connection with an alkali, which serves to free the alkaloids from their natural combinations. As aqueous or alcoholic menstrua are better solvents for alkaloidal salts than for free alkaloids, these menstrua are used *per se*, or in connection with strong acids : the latter serve the purpose of forming salts more soluble than the salts existing naturally.

The method of extraction varies with the solvents used, and with the nature of the drug and of its constituents. Maceration, percolation, and hot repercolation may be employed. That form of the latter method which consists of extraction in a Soxhlet's apparatus is rapid and expedient, but cannot be employed in case the alkaloids are readily decomposed by heat.

ISOLATION OF THE ALKALOIDS.

This step in the process must be modified according to the nature of the extracted plant principles co-existing with the alkaloids in the solution obtained by step one. In many cases, the discriminating solvent action of immiscible liquids is utilized (see United States Pharmacopoeia, page 511).*

The alkaloids are transferred from one solvent into another by freeing the alkaloids from their salts, or by combining free alkaloids with acids to form salts,—thus altering the solubilities. As the solubilities of the other principles are not thus altered, these are left behind in the original solution.

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*The plant principles which would be extracted by the solvents most commonly used are shown by reference to the following table, which also indicates the behavior of the various principles in the presence of immiscible solvents:

PLANT PRINCIPLES.	Water.	Alcohol.	Ether.	Chloroform.	Petrol'm Ether.
Cellulose and Lignin (composing cell-walls)	insol.	insol.	insol.	insol.	insol.
Starches	insol. sol in hot.	insol.	insol.	insol.	insol.
Sugars	sol.	sol.	insol.	insol.	insol.
Gums	sol.	insol.	insol.	insol.	insol.
Pectinous Bodies	sol.	insol.	insol.	insol.	insol.
Coloring Matter and "Extractive"	variable.	variable.	usually insol.	variable	variable.
Tannins	sol.	sol.	insol.	insol.	insol.
Organic Acids and Salts of the Same.	sol.	usually sol.	insol.	insol.	insol.
Chlorophyll	insol	sol.	sol.	sol.	sol.
Volatile Oils	nearly insol.	sol.	sol.	sol.	sol.
Fixed Oils	insol.	usually insol.	sol	sol.	sol.
Waxes	insol.	usually insol.	sol.	sol.	sol.
Resins	insol.	usually sol.	variable.	variable	variable.
Glucosides	sol.	sol.	insol.	insol.	insol.
Alkaloidal Salts	sol.	sol.	insol.	insol.	insol.
Free Alkaloids	nearly insol.	nearly insol.	sol.	sol	sol.

FINAL DETERMINATION.

Inasmuch as it is usually impossible to completely free the alkaloids from other principles without incurring loss of some of the alkaloid, gravimetric results are merely approximate. The search for an expedient volumetric method in which complete isolation of alkaloids would be unnecessary, first led to the use of the general alkaloidal precipitant, potassio-mercuric iodide in volumetric solution,—known as Mayer's reagent. This reagent, however, is found to give concordant results only when the titrations are conducted under precisely the same conditions, the results being affected by concentration, acidity, presence of alcohol, etc. Moreover, as no satisfactory indicator is known, the titrations must be accompanied by a tedious series of filtrations. Potassio-mercuric iodide solution is now but little used except as a qualitative alkaloidal reagent.

The afore-mentioned method has been superseded by a volumetric method based upon saturation. Alkaloids act as alkalies, and may be titrated against standard acid. This method has the advantage of being based upon definite and clearly understood chemical reactions. It is absolute and not merely comparative. It is expedient and short. But it is not applicable to such alkaloidal drugs as contain two or more alkaloids in variable relative proportions; for under such conditions, it is impossible to determine and establish a coefficient or factor. For some drugs, containing more than one alkaloid, but containing these alkaloids in relative proportions which do not vary to any great extent in different samples of the drug, a factor may be determined empirically by comparison with gravimetric results (see list of alkaloidal factors on terminal page). In the titration of alkaloids, $\frac{n}{20}$, $\frac{n}{50}$, or even $\frac{n}{100}$ volumetric solutions are employed. The use of weak volumetric solutions is advisable, because the experimental error in the titration is magnified according to the strength of the solution; and, moreover, the error is in accordance with the combining weights, which in case of alkaloids are invariably high.

The best three indicators for alkaloidal titration are Haematoxylin solution (yellow with acids, —with alkalies, purple, fading to orange-brown), Cochineal T. S. (yellow with acids,—violet with alkalies), and Brazil-wood T. S. (yellow with acids, – with alkalies, purple, fading to cherry-red). Of these, the Haematoxylin solution shows the least gradual and sharpest color changes; and for that reason, less practice than with the other two indicators is necessary to enable the operator to determine the end-reaction. Phenolphtalein is indifferent to most alkaloids. However, it can be employed in the titration of certain alkaloidal salts, since the combined acid of the salts acts on the indicator just as that much free acid would. Then, the combining weights of the alkaloids being known, their amounts may be calculated. [If the salts are not free from uncombined acid, the latter must first be neutralized with alkali, using an indicator sensitive to alkaloids.]

PROCESS I.—GENERAL.—FOR TOTAL ALKALOID.

[*Adapted from Lyons.*]

Step 1. Exhaustion.—Weigh out 10 Gm of the drug, previously dried and reduced to a moderate fine powder. Transfer to a 150 cc. conical flask, and pour upon the drug exactly 100 cc. of "Modified Prollius' Fluid."* Stopper securely, using a cork made impervious to ether,† so that the volume of fluid is not reduced by evaporation nor by the absorption of solvent by the cork.

> This precausion against concentration is essential, because (owing to the fact that much liquid is absorbed and retained by the drug tissue) an aliquot part of fluid must be taken for the assay. Obviously, an aliquot part can be taken only when the exact volume of fluid is known.

Macerate for 24 hours, shaking the flask vigorously at intervals.

Step 2. "Shaking Out."—By means of a pipette, remove exactly 50 cc. of the clear, supernatant solution, and with great care to avoid dripping, transfer through a filter into a 250 cc. separatory funnel (preferably one with a short stem). Wash the filter and funnel with 5 cc. of ether, and allow the washings to enter the separatory funnel. Drop in a small strip of litmus paper, and add 8 cc. of 3% H_2SO_4 and 8 cc. of water. Should the mixture still have an alkaline reaction, after commingling of the two layers, add more acid to slight but decided excess. [If a globular separatory funnel is used, this commingling is best accomplished by careful rotation; if the separator is pear-shaped (conical), by repeated inversion. Under no condition should the two layers be shaken together violently; as in that case, an emulsion forms which separates very slowly, entails much extra labor, and causes loss of time.]*

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*This mixed solvent consists of 250 parts (by vol.) of ether, 100 parts of chloroform 25 parts of alcohol, and 10 parts of 28% ammonia water.

†To render corks impervious to ether, coat them with chrome-gelatin, made by dissolving 8 parts of gelatin in 100 parts of boiling water and adding 2 parts of ammonium di-chromate. Allow the coating to harden by exposure to light for 24 hours.

The H_2SO_4 neutralizes the NH_4OH to $(NH_4)_2SO_4$ and converts the alkaloids into sulphates. These alkaloidal sulphates, being more soluble in the aqueous liquid, dissolve in the same, leaving much of the resins, oils, etc., behind in the etherial layer.

Next, draw off the aqueous (lower) layer into a small flask. If the two layers are more or less intermingled, and there is an emulsion layer between the clear solutions, draw off the aqueous layer only so far as it is perfectly clear. Allow no trace of the emulsion to flow into the perforation of the stop-cock, as this emulsion would subsequently be washed through into the acid water. Repeat this shaking out twice more, using 10 cc. of very dilute acid (1 part of 3% H_2SO_4 to 9 parts of water) for the first washing, and 10 cc. of water for the last. Collect the several washings in the same flask with the acid liquid first drawn off. The abstraction of the alkaloid from the etherial solution will now have been practically completed. [In some cases, this abstraction is best effected by evaporating off the Prollius' Fluid, and extracting the residue repeatedly with acid water. Enough ether is used during this extraction to dissolve the resins and fats sufficiently to enable the acid water to penetrate the varnish-like mass on stirring. The ether is subsequently evaporated and the acid water solution filtered free from resins, fats, etc. Thus, the shaking out in a separator is avoided]

Step 3. Certain plant principles other than alkaloids may have passed into the acid water, owing either to their solubility in water, or to the fact that some of the etherial liquid dissolves in the water [notice etherial odor of the acid water] and thus carries the principles into the water solution Most of these principles can be washed out with chloroform.

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*The breaking up of an emulsion can be accelerated by forced filtration;—by filtering the mixture through a pledget of cotton, contained in a small cylindrical percolator, which has been fitted through a cork into a flask, connected with an aspirator.

Return the acid water solution to the separator (which must have been thoroughly cleaned). Add 10 cc. of chloroform, rotate, draw off the chloroformic (lower) layer as sharply as possible, and reject the same.

Step 4—The acid water solution contains besides the alkaloidal sulphates, the $(NH_4)_2SO_4$ formed on acidifying, as this salt is water-soluble.

Again add 10 cc. of chloroform to the acid water solution in the separator, and then enough 10% ammonia water to render the mixture slightly but decidedly alkaline.

> The chloroform is added first and the ammonia water afterward, because alkaloids are found to be more soluble in the nascent state, and to dissolve with difficulty after having been precipitated.—The alkaloids will be dissolved by the chloroform, while the $(NH_4)_2SO_4$, being insoluble in chloroform, will remain in the aqueous layer.

Rotate the separator for some time; then draw off the chloroformic (lower) layer into a small tared flask, having a flat bottom so that the residue may be obtained in a thin layer.* In like manner, extract the alkaline liquid in the separator twice more with chloroform,† using 10 cc. each time; and add the washings to the contents of the tared flask.

Step 5.—Connect a condenser, and recover the chloroform by distillation, heating the flask on a water-bath.

Step 6.—To the varnish-like residue, consisting of fused alkaloid, add 5 cc of ether; stir well; and evaporate to constant weight in an air-bath at 95°C.‡

> The varnish-like alkaloidal residue holds traces of chloroform very tenaciously, the same being enclosed in interstices of the mass. The ether serves to dissolve the residue, and in its evaporation, the chloroform also is carried off.

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*If the residue is to be obtained by evaporating instead of distilling off the solvent, select a dish which has a flat bottom. In a round bottomed dish, the residue collects in a thick layer at the lowest point, in which state it is unfavorable for complete and rapid drying.

†In some cases, a mixed solvent is superior to chloroform for extracting the alkaloids from the aqueous layer. Ether, 1 vol. and chloroform, 3 vol., or ether, 4 vol. and chloroform, 1 vol. may be used. The first is heavier, the second lighter, than water.

‡Some alkaloids require higher heating (110°C to 120°C.), while other alkaloids are so readily decomposed by heating that it is advisable to evaporate the last traces of solvent by blowing air over the residue and to dry in a desiccator.

Step 7.—If the alkaloidal residue is much colored, dissolve in 3% H_2SO_4, using an excess, *i. e.*, enough to render the solution acid to litmus. Extract this solution with 10 cc. of chloroform. Evaporate the chloroformic solution to dryness, weigh the residue, and deduct its weight from that of the total alkaloid (see step 6). The answer is the weight of total alkaloid contained in 5 Gm. of drug. Calculate and report the per cent.

Note—Alkaloids are seldom weighed as salts; firstly, because in many cases, several series of salts—normal salts, acid salts, etc.,—are possible,—depending upon the amount of acid present; and secondly, because alkaloidal salts may exist in various degrees of hydration, and difficulty may be experienced in bringing them to a state in which they have a definite and known composition. (See Process XII.)

PROCESS II.—GENERAL.—FOR TOTAL ALKALOID IN FLUID EXTRACTS AND OTHER GALENICALS.

[*According to F. A. Thompson.*]

The special feature of this method is the use of oak sawdust (employed for its tannin), which serves to retain the coloring matter, chlorophyll, "extractive," wax, etc.

Process.—To 5 Gm. of fine oak sawdust contained in a capsule, add 10 cc. of the fluid extract; mix well; and warm at a temperature of from 38°C. to 40°C. for one hour. Transfer the dry mixture to a 200 cc. glass-stoppered bottle*; add 100 cc. of "Modified Prollius' Fluid" [see page 61]; and macerate for 30 minutes with frequent shaking. Then draw off exactly 50 cc. of the clear liquid, and proceed as directed in the first method, described on pages 61 to 64.

PROCESS III.—GENERAL—FOR TOTAL ALKALOID.

[*According to J. U. Lloyd.*]

A. FOR FLUID EXTRACTS AND OTHER GALENICALS.

To 5 cc. of the fluid extract, measured from a pipette and contained in a 2 oz. graduate having a good lip, add enough "iron mixture" (dried ferric hydroxide and sodium bi-carbonate, equal parts) to form a stiff magma (5 to 8 Gm. will be required). Mix well; add 20 cc. of chloroform; and again mix well, so as to expose all parts of the magma to the solvent action of chloroform.†

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*A bottle stoppered with a cork made impervious to ether may be employed.

The chloroformic solution should separate as a clear, transparent layer. If it does not, add a few cc of thin glucose syrup (glucose syrup and water, equal parts), and again stir.

> This addition facilitates agglutinization of the magma and separation of the chloroform;—it is especially useful in case of strongly alcoholic fluid extracts. ‡

Pour off the chloroformic solution through a filter into a 150 cc. flask. Extract the magma twice more with chloroform, using 10 cc. each time, and add the washings to the chloroformic solution in the flask.

Recover the solvent by distillation, using a water-bath. Digest the residue with 5 cc. of 3 % H_2SO_4 at 40°C. for five minutes, kneading the mass well with a glass rod to enable the weak acid to penetrate to all parts of the residue, which may contain, besides alkaloids, much resin, fats, chlorophyll, etc. Then decant the acid solution through a filter into a globular separatory funnel. Repeat the extraction twice more, using 4 cc of 1% acid each time, and decanting through the filter into the separator, so as to mix the several acid extracts. Should this liquid be dark, shake it out with 10 cc. of chloroform and reject washings. Then render alkaline with ammonia water and shake out with chloroform, using three portions of 10 cc. each.

Collect the several chloroformic solutions in a flat-bottomed beaker; evaporate to apparent dryness on a water-bath; treat the residue with 2 cc. of ether; and again evaporate. Finally, transfer to an air-bath and heat at 95°C. until constant weight has been obtained. In case of galenicals, calculate the results to amount of alkaloid in 100 cc., instead of to per cent.

Note. – In some cases, a mixed solvent of chloroform and ether is superior to chloroform alone.

B. FOR DRUGS.

Extract the drug with the menstruum used in making its fluid or solid extract. [This may be accomplished by maceration, percolation, boiling with successive portions of the solvent, or by hot repercolation, using a Soxhlet's extraction tube. If the alkaloids in the drug are very susceptible to heat, cold maceration must be resorted to.] If maceration be employed, use 10 Gm. of drug, 100 cc. of solvent, and take an aliquot part

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†The author of the process employs a mechanical mixer which is a modification of an egg-beater; but a spatula answers nearly as well.

‡If a strongly alcoholic fluid extract be diluted with water and some of the alcohol be evaporated off, thus rendering the liquid more aqueous, the chloroform separates more readily.

It should be remembered that the volume of fluid will be increased by the extractive matter which passes into solution. As a rule, seeds and barks yield about 20% by weight of extract to hydro-alcoholic solvents; dried roots and rhizomes about 40%; flowers and leaves nearly 50%.

Accordingly, in case of roots and rhizomes, 51 cc. will more nearly represent 5 Gm. of drug than will 50 cc.; in case of seeds and barks, 50.5 cc. should be taken; and in case of leaves and flowers, 51.25 cc. But for accurate work the increase in volume must be determined experimentally for each drug.

Evaporate the fluid until 1 cc. represents 1 Gm. of drug. Then proceed as directed under A.

C. FOR SOLID EXTRACTS.

Digest 1 Gm. in 20 cc. of alcohol and water in the proportion in which they are used in the manufacture of the extract. When the extract has been dissolved, take one-fourth, and proceed as for Fluid Extracts.

Characteristic Features of the Process.

(1.) The use of sodium bi-carbonate in the place of caustic alkali for the purpose of freeing the alkaloids from their natural combinations;—caustic alkali being capable of hydrolysing, or otherwise decomposing certain delicate alkaloids, such as atropine.

(2.) The use of ferric hydroxide to "fix" tannins, organic acids and salts, certain coloring principles, salts of mineral acids, some chlorophyll, etc.

(3.) The use of enough "iron mixture" to absorb the water of the fluid extract, thus forming a dough-like magma from which the chloroform solution can be obtained by decantation. This saves one "shaking-out,"—a process which is troublesome and tedious at best.

PROCESS IV.—FOR NUX VOMICA AND SIMILAR DRUGS.

[*According to C. C. Keller.*]

The drug is first extracted with ether to remove fat. This may be accomplished by hot repercolation in a Soxhlet's tube, operating on 15 Gm. of drug, and using 100 cc. of ether as solvent. The extraction is completed when 10 cc. of percolate cease to leave a residue on evorporation. The etherial fat solution must be saved. Transfer the drug, which has been deprived of fat, to a tared 250 cc. wide-mouthed bottle, and add enough ether to bring the weight of drug and solvent up to 100 Gm. Next add 50 Gm. of chloroform, and finally 10 cc. of 10% ammonia water. Cork securely with a stopper impervious to ether, and agitate vigorously at intervals during half an hour.

While the drug is being macerated, shake out the etherial fat solution several times with acid water, with a view to the removal of the alkaloid which may have been extracted by the ether. Use for the first washing, 5 cc. of 5% HCl, and for subsequent washings, very dilute acid (1 cc. 5% acid to 20 cc. water). Next add the mixed acid washings, which should measure just 25 cc., to the drug and solvent in the tared flask, and thoroughly incorporate by shaking.

The water in the ammonia and acid washings serves to agglutinate the drug, so that the etherial layer may be decanted.* When this has been done, pour 75 cc. more of ether-chloroform (for Nux Vomica, ether 2 parts, chloroform, 1 part) over the moist drug, which must still be alkaline; shake well; and again decant. Repeat the extraction a third time, using 50 cc. of the solvent.

Collect the several ether-chloroform solutions in a tared flask and recover the solvent by distillation, using a water-bath. Pour 5 cc. of absolute alcohol (or ether) over the varnish-like residue, and evaporate to constant weight in an air-bath at 95°C. to 100°C.

The gravimetric results are checked by titrating the alkaloidal residue against standard acid as follows:

Dissolve the residue in 5 cc. of chloroform, warming if necessary. To the solution add 40 cc. of ether, 10 cc. of water, 1 drop of alcoholic iodo-eosin solution (1%), and a measured excess (10 cc) of $\frac{n}{10}$ HCl. Agitate well; then "titrate back" with

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*Instead of decanting all of the etherial solution, an aliquot part may be taken, as advocated by Keller.

$\frac{n}{10}$ NH_4OH, corking the flask and shaking after each addition, until the aqueous layer acquires a permanent rose color. To make the color changes more apparent, place a sheet of white paper under and behind the titration flask.

Calculation.- Deduct the amount of $\frac{n}{10}$ NH_4OH used from the measured excess of $\frac{n}{10}$ acid. Each cc. of the remainder of the $\frac{n}{10}$ acid indicates .0364 Gm. of mixed strychnos alkaloids; it being assumed that the Brucine and Strychnine exist in equal proportions.

Charateristic Features of the Process.

(1.) The preliminary extraction of fat.

(2.) The use of menstruum consisting principally of ether, it having been proven that ether yields the purest alkaloidal residues. Chloroform is added in case the alkaloids are not very ether-soluble. Alcohol is never used in the extraction, as it extracts (from most drugs) principles from which the alkaloids cannot be completely separated by subsequent operations.

(3.) The use of enough aqueous liquid in the menstruum to agglutinate the drug, so that the solution may be decanted clear.

(4.) The titration of the residue in presence of two immiscible liquids, one of which holds the coloring matter of the residue, so that the color changes of the indicator, which is in the other layer, are not obscured.

PROCESS V.—FOR TOTAL ALKALOID IN EXTRACT OF NUX VOMICA.

[*According to U. S. Pharmacopoeia of 1890, Page 154.*]

Explanation.—The extract is first dissolved in a hydro-alcoholic menstruum, made alkaline with ammonia water. This solution is extracted with chloroform; the chloroformic solution is evaporated to dryness; the residue is dissolved in excess of standard acid and is retitrated with standard alkali, Brazil-wood T. S. being used as indicator. The $\frac{n}{10}$ factor, .0364, is obtained by adding the factor for brucine, .0394, to that for strychnine, .0334, and dividing the sum by two, on the assumption that the two alkaloids exist in equal proportions.

Note.—Beckurts found the ratio of strychnine to brucine in Nux Vomica to vary between 43 : 57 and 54 : 46.

PROCESS VI.—FOR TOTAL ALKALOID IN NUX VOMICA, IPECAC, BELLADONNA, ETC.

[*According to Kebler's Modification of Keller's Method.*]

Place 10 Gm. of the dry drug in a 250 cc. flask; add 25 Gm. of chloroform and 75 Gm. of ether; stopper securely; and agitate well for several minutes. Then add 10 Gm. of 10% ammonia water, and shake well, which causes the suspended powder to agglutinate into a lump, and the etherial liquid to become perfectly clear. Then proceed as directed under either *A.* or *B.*

A. For Nux Vomica and Ipecac.—Decant exactly 50 Gm. of etherial solvent [representing 5 Gm. of drug] into a beaker; evaporate the solvent on a water bath; add 10 cc. of ether; and evaporate to constant weight, which must be recorded.

Dissolve the residue in 15 cc. of alcohol by heat; add water to slight permanent turbidity, cochineal indicator, and a measured excess of $\frac{n}{10}$ acid; then titrate back with $\frac{n}{100}$ alkali.

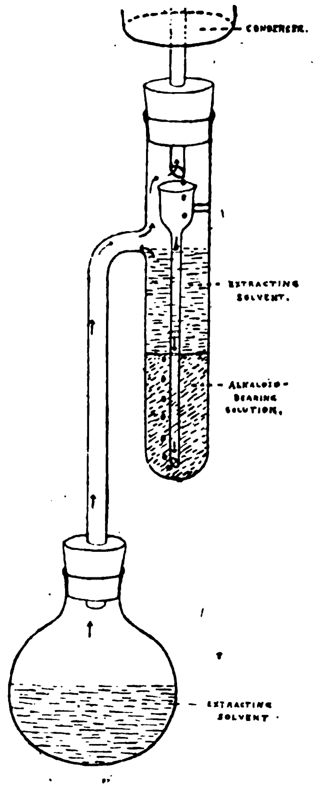
B. For Belladonna and Similar Drugs.—Transfer 50 Gm. ot the clear etherial liquid to a separatory funnel, and shake out with three portions [20, 15, and 10 cc.] of acidulated water, using 2% H_2SO_4 for the first, and very weak acidulated water [about ¼% H_2SO_4] for the subsequent washings. Collect the several acid solutions in a second separatory funnel; render alkaline with 1% ammonia water; and shake out with the chloroform-ether [30 cc. to 15 cc.], using respectively 20 cc., 15 cc., and 10 cc. for the three washings. Collect the chloroform-ether solutions in a tared flask, and recover the solvent by distillation. Treat the residue with 8 cc. of ether, evaporate, add 8 cc. more of ether, and dry to constant weight, which should be recorded. Then dissolve and titrate the residue as directed under *A.* For indicator use haematoxylin.

Note.—Fluid extracts may be assayed by the same method, except that the aliquot part of etherial solvent must be transferred by means of a pipette, as it cannot readily be decanted.

PROCESS VIII.—FOR TOTAL ALKALOID IN COLCHICUM ROOT AND SEED.

[*According to K. Schwickerath.*]

Macerate 20 Gm. of drug (powdered fine) for 12 hours in 100 cc. of the following mixture:—1 cc. of 28% ammonia water, 5 cc. of alcohol, 24 cc. of chloroform, and 70 cc. of ether. Decant through a filter exactly 50 cc. of the etherial liquid (representing 10 Gm. of drug) into a beaker containing 8 cc. of distilled water, and render the mixture acid by the addition of acetic acid. Evaporate off the etherial liquid, using a water-bath. Filter the acid water solution through cotton into a perforator (extraction apparatus, see accompanying illustration), and wash the beaker and cotton with a little water, catching the washings in the perforator. Put 80 cc. of petroleum ether into the flask connected with the perforator, and by heating, cause the petroleum ether to wash through the acid water for one hour. [This serves to remove fats, coloring matter, etc.] Decant the petroleum ether as completely as possible from the acid water solution, and reject the former. Next, render the acid water solution alkaline by the addition of crystalline sodium carbonate, and again extract for one hour in the perforator, this time using a mixture of 60 cc. of ether and 20 cc. of chloroform. To prevent bubbles from the extracted solution passing into the flask, place a layer of cotton at the mouth of the tube. Recover the solvent from the alkaloidal solution by distillation and dry the residue at a temperature below 100°C. Weigh.



APPARATUS FOR EXTRACTION OF FLUIDS.

PROCESS VIII.—FOR TOTAL ALKALOID IN ACONITE ROOT.

[*According to Farr and Wright.*]

Moisten 20 Gm. of the drug, powdered moderately coarse, with a menstruum of 77 volumes of official alcohol and 23 volumes of water. Pack in a percolator of convenient size, and percolate with the same menstruum, slowly but continuously, until the drug is exhausted,* which will have been accomplished when about 160 cc. of percolate have been obtained.

Evaporate the percolate on a water bath until all alcohol has been dissipated. Then add 15 cc. of 5% H_2SO_4 and filter, washing the precipitate and filter with .5% H_2SO_4 to prevent loss of alkaloid. Extract the acid water solution with chloroform to remove coloring matter, and in turn, wash the chloroformic solution with a little acid water to recover traces of alkaloid which may have been abstracted by the chloroform. Reject the chloroformic solution, but add the acid washings to the alkaloidal acid water solution. To the latter, add K_2CO_3 to slight excess, and extract the alkaloids by agitating with three successive portions of chloroform of 20 cc. each. Then, having washed the united chloroformic solutions with a little water (this being rejected), transfer the solution to a tared flask, and recover the chloroform by distillation from a water-bath. Dry the residue at 100°C. and weigh.

Note.—This method can be made applicable to tinctures, fluid extracts, and solid extracts.

PROCESS IX.—FOR TOTAL ALKALOID IN BELLADONNA ROOT

[*According to Dunstan and Ransom.*]

Exhaust 20 Gm. of the drug, which should be in fine powder, by hot percolation, or by repercolation in a Soxhlet's extraction tube, using a menstruum of equal volumes of chloroform and absolute alcohol [see foot-note under Process VII]. Transfer the percolate to a separator, and wash out with three successive portions [20 cc., 20 cc., and 10 cc.] of acidulated water [1 part 5% H_2SO_4 to 19 parts water]. Extract the mixed acid washings with 10 cc. of chloroform; then render alkaline with 10% ammonia water, and abstract the alkaloid by means of chloroform, using two portions of

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*Catch a few drops of weak percolate on a watch glass; evaporate to dryness; re-dissolve the residue in a few drops of acid water; and test the solution by adding a drop of Mayer's reagent, holding the watch-glass over a black surface. If no cloudiness is observed, the drug has been exhausted by alkaloid.

20 cc. and one of 10 cc. Wash the mixed chloroformic solutions with a little water, and reject the washings. Then transfer to a flask; recover the chloroform; add a few drops of ether or absolute alcohol; and dry to constant weight at 95°C.

For Belladonna Leaves, use absolute alcohol in the extraction; for Hyoscyamus and Stramonium, use 50% alcohol. Stramonium Seed, however, requires a preliminary extraction of the fat by means of petroleum ether.

PROCESS X.--FOR TOTAL ALKALOID IN FLUID EXTRACT OF BELLEDONNA.

[*According to the British Pharmacopoeia, 1898.*]

Shake 10 cc. of fluid extract with 10 cc. of chloroform, 50 cc. of water, and an excess of ammonia water. Separate the chloroformic solution and repeat the washing out twice more with 10 cc. of chloroform. Shake out the mixed chloroformic solutions with 15 cc. of 3% H_2SO_4. Repeat. Wash the mixed acid liquids with 3 cc. of chloroform, and reject washings; then agitate with 10 cc. of chloroform, and add ammonia water to excess. Separate, and repeat the washing out twice more. Wash the mixed chloroformic solutions with 5 cc. of water, containing 1 drop of 10% ammonia water. Reject the water. Evaporate or distill off the chloroform from a water-bath. Dry the residue at 100°C. and weigh.

Dissolve the residue in just 10 cc. of $\frac{n}{10}$ HCl, and retitrate with $\frac{n}{100}$ NaOH, using cochineal tincture as indicator [yellow with acids, purple with alkalies].

Calculation.—Deduct the volume of $\frac{n}{100}$ NaOH required from 10 times the volume of $\frac{n}{10}$ acid used, and multiply the remainder by the $\frac{n}{100}$ factor for Belladonna alkaloids,—.00289. The product will be the amount in grammes of alkaloid in 10 cc. of fluid extract.

PROCESS XI—FOR TOTAL ALKALOID IN COCA LEAVES.

[*According to Gunn's Modification of Lyons' Methods.*]

Moisten 5 Gm. of powdered drug with 2% ammonia water, and allow to stand for ½ hour. Then pack in a cylindrical percolator of convenient size, and percolate with ammoniated ether [10% ammonia water, 3 vol.,—ether, 97 vol.] until the percolate ceases to react with Mayer's reagent. [About 100 cc. will be required to exhaust the drug.] Shake out the alkaline ether solution with three successive portions of 2% HCl, using 20 cc., 20 cc., and 10 cc. Extract the mixed acid water solutions with 15 cc. of ether to remove coloring matter, and reject the etherial solution. Then render alkaline with 10% ammonia water, and wash out the alkaloid with ether, using 3 portions of 20 cc. each. Recover the ether by distillation, dry the residue at 75°C., and weigh.

Dissolve the alkaloidal residue in a measured excess of $\frac{n}{10}$ HCl, add cochineal indicator, and retitrate with $\frac{n}{100}$ KOH. The $\frac{n}{100}$ factor for Coca alkaloids is .00303.

For Fluid Extract of Coca, use Lloyd's method.

PROCESS XII.—FOR TOTAL ALKALOID IN CONIUM.

[*Adapted from Cripps.*]

Mix 5 Gm. of the drug in fine powder with an equal weight of sand, and extract in a Soxhlet's tube with a menstruum consisting of 25 vol. of absolute alcohol, 15 vol. of chloroform, and 10 vol. of chloroform saturated with HCl gas.* When the drug has been exhausted of alkaloid [test with Mayer's reagent], agitate the liquid 3 times with water, using 25, 20, and 10 cc. Wash the mixed aqueous solutions with chloroform, which abtracts coloring matter, etc., but does not abstract the alkaloid, as the latter exists as a salt—hydrochloride—which is much more soluble in the water. Then make the liquid alkaline with ammonia water, and abstract the alkaloid with chloroform, using 3 portions of 20, 15, and 10 cc. Wash the united chloroformic solutions with 10 cc. of water made alkaline with a few drops of ammonia water, and reject the washings. Then proceed as directed under either A. or B.

A. Pour the chloroformic solution into 40 cc. of ether saturated with HCl gas. Recover the solvents, and dry the residue (coniine hydrochloride) to constant weight at a temperature not exceeding 90°C. 163.5 parts of Coniine Hydrochloride are equivalent to 128 parts of the free alkaloid.

B. Treat the chloroformic solution with a measured excess of

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*Generate HCl by action of H_2SO_4 on NaCl. Dry the gas by passing it through a wash-bottle containing H_2SO_4.

$\frac{n}{10}$ HCl, agitate, and determine the excess of acid with $\frac{n}{100}$ alkali, using cochineal indicator. 1 cc. of $\frac{n}{100}$ acid=.00128 Gm. Coniine.

Note.—As Coniine is a volatile alkaloid, it cannot be weighed as a free base, but must first be converted into a non-volatile salt.—If the HCl were not present in the extracting solvent, the Coniine would circulate continuously through the Soxhlet's tube with the solvent; the HCl forms Coniine Hydrochloride, which is non-volatile and hence remains in the flask.

PROCESS XIII.—FOR TOTAL ALKALOID IN GELSEMIUM ROOT.

[*According to K. Schwickerath.*]

Macerate 20 Gm. of the drug in 100 cc. of "Modified Prollius' Mixture." Remove 50 cc., representing 10 Gm. of drug, and filter. Add 8 cc. of water and enough 3% H_2SO_4 to render slightly but decidedly acid. Evaporate off the ether, chloroform, and alcohol on a water-bath. Filter the acid solution through cotton into a perforator, wash with petroleum ether for 1 hour, and reject washings. Then render alkaline with 5% ammonia water, and extract the alkaloid with ether for 2 hours, or until all alkaloid has been abstracted. Recover the ether, dry the residue at 80°C., and weigh.

Note.—In place of extracting in a perforator, a separatory funnel may be employed in the usual way.

PROCESS XIV.—FOR TOTAL ALKALOID IN IPECAC.

[*According to C. C. Keller.*]

Extract 10 Gm. of powdered drug by percolation with ether, until all fat has been removed. Then transfer the drug to a 150 cc. flask, add 60 cc. of ether and 25 cc. of chloroform, and mix thoroughly by agitation. Next, add 10 cc of 10% ammonia water to liberate the alkaloid. Agitate at intervals during one hour; then add 5 cc. more of ammonia water, which causes the drug to thoroughly agglutinate and the etherial solvent to separate clear. Remove exactly 50 cc. of the etherial liquid to a tared conical flask, distill off the solvent, and treat the residue twice with 5 cc. of ether, removing the latter after each addition by forcing a current of air through the flask. Dry in a desiccator and weigh.

Dissolve the residue in 10 cc. of absolute alcohol, add 3 drops of alcoholic haematoxylin solution (1%), and titrate with $\frac{n}{10}$ HCl until the violet color has faded to a pale yellow.

Calculation.—The part operated on represents 5 Gm. of drug. Each cc. of $\frac{n}{10}$ acid indicates .0254 Gm. of alkaloid.

PROCESS XV.—FOR TOTAL ALKALOID IN FLUID EXTRACT OF IPECAC.

[*According to the British Pharmacopoeia, 1898.*]

Dilute 20 cc. of the fluid extract with 20 cc. of water, and evaporate off the alcohol on a water-bath. To the warm solution, add an excess of Solution of Lead Subacetate (see U. S. P., page 237), *i. e.*, until it ceases to cause precipitation. Filter, wash the precipitate and filter-paper with water, and catch the washings in the first filtrate. Then, to remove excess of lead from the filtrate, add 10% H_2SO_4 as long as a precipitate falls. Filter, wash, and add washings to the filtrate. Transfer the filtrate to a separator, make alkaline with ammonia water, and shake out with 25 cc. of chloroform. Repeat the shaking out with two portions of chloroform of 10 cc. each. Evaporate the mixed chloroformic solutions, moisten residue with ether and dry to constant weight at a temperature below 80°C.

PROCESS XVI.—FOR TOTAL ALKALOID IN TEA

[*According to Chemists of U.*
of Agriculture

To 3 Gm. of tea or coffee, cont
flask, add 250 cc. of water; heat
this temperature for 30 minu
drug which may collect
frothing may be lessened by
liquid.] Replace the water lo
filled nearly to the neck. Cool, an

[U. S. P.] until it ceases to cause further precipitation [about 5 cc. will be required]. Make up the volume to 300 cc., mix thoroughly, and filter. Reject the first portion of filtrate; then collect exactly 50 cc. [representing ½ Gm. of drug]. Treat this aliquot part of the filtrate with H_2S to remove lead as PbS; boil off excess of H_2S; filter into a separatory funnel; and wash the PbS precipitate with hot water, to recover the caffeine absorbed by the residue. [Instead, 100 cc. of filtrate may be collected and treated with H_2S, and 50 cc. of the second filtrate be taken; thus the washing of precipitate is avoided.] Extract the water solution in the separator 7 times with chloroform, using 15 cc. each time. * Recover the chloroform by distillation, and dry the caffeine to constant weight at 75°C. [This will require about 2 hours.] The residue is the Caffeine in ½ Gm. of drug; hence multiply by 200 for per cent.

PROCESS XVII.—FOR TOTAL ALKALOID IN KOLA NUT.

[*According to Carls.*]

Mix 10 Gm. of the drug in very fine powder with 1 Gm. of freshly slaked lime and 20 Gm. of 80% alcohol. Evaporate down to 14 Gm. on a water bath, powder the residue in a mortar, transfer to a flask provided with a condenser, and digest for 1 hour on a water-bath with 35 cc. of a menstruum composed of 100 vol. of chloroform and 20 vol. of alcohol. Filter, and digest the residue 3 times more in the same manner. Evaporate the united filtrates to dryness. Treat the residue with 10 cc. of boiling water made acid with 5 drops of 1% H_2SO_4; filter; and repeat the extraction twice more. Evaporate the united aqueous solutions to dryness and weigh.

Note.—The alkaloids exist naturally as glucosides, which are decomposed in the process.

PROCESS XVIII.—FOR TOTAL ALKALOID IN PILOCARPUS.

[*According to M. Conroy*]

Extract 10 Gm. of drug by percolation with 50% alcohol. Evaporate to a syrup, add 15 cc. of water, and wash with chloroform to remove chlorophyll, etc. Render alkaline with sodium carbonate, and extract the alkaloid with chloroform. If necessary, extract the chloroform solution with acid water; then make alkaline, and abstract the alkaloid with chloroform. Treat the residue with ether, and evaporate to constant weight.

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* It is very difficult to abstract Caffeine from water solution by means of chloroform.

PROCESS XIX.—FOR TOTAL ALKALOID IN SABADILLA.

[*According to C. C. Keller.*]

Macerate 15 Gm. of drug in a 300 cc. flask with 150 cc. of ether for one hour; add 10 Gm. of 10% ammonia water, shake well, and macerate for 3 hours. Then decant just 100 cc. of the etherial solution (representing 10 Gm. of drug) and proceed as in the Assay of Ipecac (see page 74).

PROCESS XX.—FOR TOTAL ALKALOID IN PHYSOSTIGMA.

[*According to P. Macewan.*]

Exhaust the drug by hot percolation with 60% alcohol. Evaporate off the alcohol, add lead sub-acetate solution until it ceases to cause precipitation, and filter. Remove excess of lead by running in H_2S; filter; and boil off the excess of H_2S. Render alkaline with ammonium carbonate, and abstract the alkaloid with chloroform. Recover the solvent, dry, and weigh.

DETERMINATIONS OF "PRINCIPAL" ALKALOID.

In some drugs, the medicinal activity does not depend upon the percentage of the total alkaloid so much as upon the percentage in which one certain alkaloid is contained in the drug. Thus, Brucine has but little therapeutic worth, and the strength of the drug (Nux Vomica) is really in proportion to the amount of Strychnine contained therein,—not in proportion to the amount of Brucine and Strychnine, *i. e.*, total alkaloid. The therapeutic worth or strength of Opium is primarily in accordance with its Morphine strength, and Cinchona is valued therapeutically as well as commercially by its Quinine strength.

PROCESS XXI.—FOR QUININE IN CINCHONA.

[*According to the U. S. Pharmacopoeia of 1890, page 91.*]

Explanation.—The first step is identical with that in the determination of total alkaloid. The process for the estimation of the Quinine in the alkaloidal residue is based upon the relative solubility in ether, of the Quinine and the other Cinchona alkaloids,—it being assumed that by percolating the alkaloidal residue from 5 Gm. of drug with ether, as per directions, the first 10 cc. of percolate will contain *all* the Quinine, together with some of the less soluble Cinchona alkaloids. *How much* of the residue consists of these *other alkaloids* is found by obtaining a second 10 cc. of percolate in precisely the same manner, evaporating this solution to dryness, and weighing the residue. It is assumed that the first residue will contain an equivalent amount of the other alkaloids, as both 10 cc. of percolate are saturated. Therefore, by deducting the weight of the second residue from the weight of the first, the weight of Quinine in the first residue may be ascertained.

Notes.—(1.) In evaporating the chloroformic solution with powdered glass, a very moderate heat (less than 60°C.) should be employed, as otherwise spurting occurs, thus occasioning loss of alkaloid.

(2.) The glass serves to render fit for percolation a residue which would otherwise form as a varnish-like coating on the inner surface of the vessel.

PROCESS XXII.—FOR MORPHINE IN OPIUM.

[*According to the U. S. Pharmacopoeia of 1890, page 262*]

Explanation.—(1.) The first step in the official process consists in repeatedly extracting the Opium by maceration in water, which dissolves all the Morphine, existing as a salt, and at the same time dissolves most of the other alkaloids and many other principles.

(2.) As the morphine is to be isolated by precipitation, it is necessary to concentrate the rather weak aqueous extract in order to prevent the loss of much Morphine in the mother-liquor, in which this alkaloid is slightly soluble (about 1 part in 4350). Accordingly, the 320 cc. of fluid are directed to be concentrated to 14 Gm.

(3.) In transferring the liquid to a flask, it is necessary to wash the dish with a small volume of water, which increases the amount to 20 Gm.

(4.) Alcohol, ether, and ammonia water are next added. The ammonia serves to free the alkaloids from their salts. With the exception of Morphine, these alkaloids are soluble in ether, and are held in solution by the same, while Morphine, being practically insoluble in this solvent (1 part in 4000), is precipitated. The presence of two immiscible liquids, ether and water, renders precipitation more nearly complete. The alcohol is added to hold in solution certain principles which would otherwise be precipitated with the Morphine, and would thus contaminate the latter.

(5.) After transferring the crystals to a filter, adhering mother-liquor is removed by washing first with water, then with alcohol. The latter is saturated with the alkaloid, in order that no Morphine crystals be dissolved in the washing. [As Morphine is somewhat soluble in water, the use of morphinated water also is advisable.]

This method serves well for comparative assays, but fails to give absolute results, as the precipitated Morphine is more or less impure. On the other hand, some Morphine is held in solution by the alcohol and other solvents, and some is lost in the washing of the precipitate.

The purity of the precipitate may be determined (1) by titrating an aliquot portion against standard acid; (2) by treating another portion with baryta water (which dissolves Morphine), and weighing the undissolved residue; (3) by incinerating and weighing the ash in a third portion of the precipitate.

Notes.—(1.) In case lump Opium is to be assayed, care must be exercised to get a truly representative sample.

(2.) To remove the principles which sometimes prevent the precipitation of the morphine, the use of $BaCl_2$ or Sodium Salicylate has been suggested.

(3.) Morphine cannot be obtained anhydrous below 110°C.

(4.) The U. S. P. process for Tincture and Extract of Opium are in the main identical with that for the crude drug.

PROCESS XXIII.—FOR MORPHINE IN TINCTURE OF OPIUM.

[*According to the British Pharmacopoeia, 1898.*]

Evaporate 80 cc. of the tincture down to 30 cc.; mix the residue with 3 Gm. of freshly slaked lime, $Ca(OH)_2$; and add water to make up to 85 cc. Let stand for ½ hour, stirring occasionally.

Filter off 50 cc. (representing the same volume of original tincture) and add to the same, 5 cc. of 90% alcohol and 30 cc. of ether. Shake, and then add 2 Gm. of NH_4Cl. Shake well at frequent intervals during ½ hour, and set aside for 12 hours, in which time the precipitation of Morphine will be practically completed. Filter; wash the residue with morphinated water; and dry the crystals, first by gentle pressure between filter papers (to absorb morphinated water), then at 55°C., and finally for 2 hours at 110°C. Weigh.

Take .3 Gm. of the alkaloidal residue, dissolve in a measured excess of $\frac{n}{10}$ H_2SO_4, and titrate back with $\frac{n}{10}$ NaOH; or, add $\frac{n}{10}$ H_2SO_4 to the residue until the liquid, after boiling, slightly reddens blue litmus paper. Add to the weight (in total amount of crystals) of anhydrous Morphine thus indicated ($\frac{n}{10}$ factor,—.0303), .05 Gm., which covers loss of Morphine in the process.

Explanation.—The $Ca(OH)_2$ frees and dissolves the Morphine; it also precipitates meconic acid and meconates as insoluble calcium meconate, and removes resinous matter, forming insoluble compounds with the same. On addition of the NH_4Cl, the $Ca(OH)_2$ is converted into $CaCl_2$, the solution of which has no solvent action on Morphine. Free NH_4OH is formed at the same time, but neither does this, nor do the solvents,—alcohol, ether, and water, dissolve more than traces of Morphine. The latter therefore precipitates out. Precipitation is rendered more nearly complete by the presence of ether, which serves the additional purpose of holding in solution other alkaloids and principles. The alcohol, too, serves the purpose of preventing the precipitation of certain principles—coloring matter, etc.

PROCESS XXIV.—FOR STRYCHNINE IN FLUID EXTRACT OF NUX VOMICA.

[*According to the British Pharmacopoeia, 1898.*]

Evaporate 10 cc. of the fluid extract on a water-bath to a thick syrupy liquid, and dissolve the residue in 20 cc. of water by the aid of heat. Transfer the solution to a separator, make alkaline with 5 Gm. of sodium carbonate dissolved in 25 cc. of water, and shake out with 10 cc. of chloroform. Repeat the shaking out with chloroform twice more. Extract the mixed chloroformic solutions in a separator with three portions of 10 cc. each, of 2% H_2SO_4.

Dilute the united acid liquids with water to 175 cc., and shake well and frequently in a glass-stoppered bottle during half an hour with 25 cc. of 5% potassium ferrocyanide solution, which precipitates the Strychnine as ferrocyanide. Transfer the precipitate to a filter, and wash the flask, filter, and precipitate with ¼% H_2SO_4 to remove Brucine, etc. When the washings cease to come through bitter, carefully wash the precipitate into a separator with water.* Add 5 cc. of 10% ammonia water, which liberates the Strychnine, and extract the latter with chloroform, using 3 portions [15 cc., 10 cc., and 10 cc.]. Catch the chloroformic solutions in a tared beaker, dispel the chloroform, dry the residue at 95°C. for one hour, and weigh.

PROCESS XXV.—FOR HYDRASTINE IN HYDRASTIS.

[*According to C. C. Keller.*]

To 12 Gm. of the drug in fine powder, add 120 cc. of ether, and, after a few minutes, 10 cc. of 10% ammonia water. Agitate during ½ hour, at the end of which time add 5 cc. of water, which, on shaking, causes the drug to agglutinate. Pour off 50 cc. of etherial solvent (representing 5 Gm. of the drug), and agitate with 25, 25, and 10 cc. of 1% HCl. Render the united acid washings alkaline with ammonia water, and wash out the Hydrastine with 3 portions of ether. Recover the ether, dry, and weigh the alkaloid. Hydrastine cannot be titrated satisfactorily, as it is but feebly alkaline.

PROCESS XXVI.—FOR HYDRASTINE IN FLUID EXTRACT OF HYDRASTIS.

[*According to Beckurts.*]

To 10 cc. of the fluid extract, contained in a 100 cc. cylinder, add 20 cc. of a saturated solution of lead acetate, and enough water to make up to 100 cc. Shake well, and filter off 50 cc. To the filtrate, add 10 cc. of diluted H_2SO_4, which precipitates out excess of lead and most of the Berberine, and again dilute to 100 cc. Agitate, allow the mixture to settle, and filter off 50 cc. (representing 2.5 cc. of the original fluid extract). Then heat on a water-bath to expel alcohol, transfer to a separator, wash out with ether, and reject the washings. Next render alkaline with ammonia water, and extract the alkaloid with ether, which dissolves out the Hydrastine, but not the Berberine. Expel the solvent, dry, and weigh.

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*Both precipitate and filter may be transferred to the separator.

Note.—To determine Berberine, add to 10 cc. of the fluid extract, 1 Gm. of 20% H_2SO_4 and 5 Gm. of 12.5% HCl, and keep at a low temperature for 12 hours. Collect the crystals of Berberine Sulphate which separate out, wash them with acidulated water, dry, and weigh. 90 parts of the salt are equivalent to 70 parts of the free alkaloid.

ASSAY OF DIGESTIVE FERMENTS.

PEPSIN.

The strength (proteolytic power) of pepsin is expressed by the amount of coagulated egg-albumen that the pepsin will dissolve under certain conditions and in a certain length of time. Thus, Pepsin "1 : 3000" means that one part of the pepsin will dissolve 3000 parts of coagulated egg-albumen, under the conditions specified in the pepsin assay of the U. S. P., which conditions must be strictly adhered to in order to get concordant results.

Process.—Follow pharmacopoeial directions. If the albumen is not all dissolved on the first trial, repeat the tests, taking each time a larger amount of solution B, until the albumen is practically dissolved after digestion for six hours.

Calculation.—Suppose 6 cc. of solution B were required. Then, 6 cc. : 5 cc. :: x : 3000. $x = 2500$.

PANCREATIN.

The valuation of pancreatin consists in determining how much cows' milk can be peptonized by a given weight of the ferment, and under specified conditions. The end reaction is determined by adding HNO_3, which coagulates the albuminoids existing in milk, but does not affect peptones.

DIASTASE AND EXTRACT OF MALT.

The value of diastase depends upon its power to convert starch into sugar. In its assay or the assay of its preparations this power is determined.

DETERMINATION OF FIXED OIL IN EMULSION.

Process.—Weigh a small beaker containing 5 cc. of the emulsion. Of this pour about 2 or 3 cc. upon a strip of filter-paper which yields no extractive to anhydrous ether, in such a way that it is distributed in a thin layer over the surface of the strip. [A paper of this kind, used in the determination of fat in milk, may be bought for this purpose; or, ordinary filter-paper may be prepared by cutting it into strips, rolling these up into the form of a cylinder, and extracting them for several hours with anhydrous ether in a Soxhlet's continuous extraction apparatus.] Again weigh the beaker and contents, and calculate the amount taken, by difference. Then carefully roll up the strip of paper in the form of a cylinder, taking care that no emulsion is lost, but that all is absorbed by the filter-paper, and thoroughly drive off the water in the absorbed emulsion by heating one hour in an air-bath at 105°C., the roll of filter paper being kept lying on its side on a piece of glass or a pill-tile. Transfer the roll to a Soxhlet's tube; connect below with a tared flask containing 75 cc. of anhydrous ether, and above with a reflux condenser. Then apply heat, and when the roll has been washed 12 or 15 times by the anhydrous ether, withdraw the flame, disconnect the apparatus, and connect the flask with an ordinary Liebig's condenser. Distill off the ether, driving off the last traces from the residue of extracted oil by heating the flask for 15 minutes in an air bath at 105°C. Cool and weigh. Calculate percentage by weight, of oil in the emulsion. If the percentage of oil by volume is desired this can be calculated from the percentage by weight if the specific gravities of the oil used, and of the finished emulsion are known.

Example.—An emulsion having a specific gravity of 1.10 contains 25% by weight of Cod Liver Oil whose specific gravity is .917. What is the percent of oil by volume?

100 cc. of emulsion weigh 110 Gm. and contain (110.×.25) or 27.5 Gm. of oil, which measure $\frac{27.5}{.917}$ or 30 cc. $\therefore$ The emulsion contains 30% of oil by volume.

Note.—The preceding process could of course not be used for emulsions of volatile oils.

POLARISCOPIC DETERMINATIONS.

In that kind of polarized light known as *plane* polarized, the transverse vibrations [which in ordinary light occur in all planes at right angles to the direction of the wave] are restricted to one plane only.— Light becomes plane polarized by reflection from polished surfaces; also in its passage through certain bodies of crystalline structure, such as Tourmaline and Iceland Spar,—the latter being the usual means of obtaining plane polarized light for polariscopic determinations.

But a ray of light, in passing through a crystal of Iceland spar is doubly refracted; that is, the ray is split into two rays, one of which is refracted [turned from its original course] to a greater extent than the other. The planes of the vibrations of these two rays are at right angles to each other, while for polariscopic use it is necessary that the vibrations be in one plane only. One of these rays must therefore be eliminated. To accomplish this, the Iceland spar is not used in its original form, but is cut diagonally through its long axis [at right angles to the rhomboid ends, the latter having been ground to such angles that the cut will coincide with the shorter diagonal], and, after the polishing of the two surfaces, the halves are joined together with a layer of Canada balsam. This balsam layer reflects the ray refracted to the greater extent, while the other ray strikes the balsam at such an angle that it can enter and pass through.

In the instrument known as the polariscope, there are two such modified Iceland spar crystals (Nicol's prisms) placed in line with each other. When these two prisms exactly coincide, the ray of light emerging from the first prism will also pass through the second. But if either one of these prisms be rotated, light emerging from the first will be intercepted by the second. Thus, if one prism be turned completely about its axis, there will be two points at which the prisms will exactly coincide, and at which the field of the polariscope appears brightest; and two points at which all light will be excluded. These two prisms, one of which is stationary and known as the polarizer, the other admitting of rotation and known as the analyser, are the essential parts of a polariscope. As it would be difficult to take cognizance of slight changes in brightness, all modern polariscopes have devices for making a very slight change from coincident positions of the Nicol's prisms more apparent. In the Laurent instrument, a thin quartz plate, cut parallel to its axis, is so placed between the two Nicol's prisms that the field traveled by the rays is just half covered by the quartz. The polarizer is set so that its plane is nearly but not quite parallel to the axis of the quartz. The rays passing through the quartz plate are slightly turned upon their axes; and since the plane of their vibrations is no longer parallel to the plane of vibrations of the rays which do not pass through the quartz, the analyser can coincide with only one side at a time, thus giving the field the appearance of two half moons, one light,—the other dark. When the analyser is set to correspond as nearly to the one side as to the other, the field appears evenly illuminated. This point is taken as the zero-point, and the instrument is adjusted accordingly.

If an optically active substance (see United States Pharmacopoeia) be placed between the polarizer and analyser thus adjusted, the field will cease to be homogeneous, due to the fact that the plane of vibration of the polarized rays has been rotated (turned on its axis). The original view of the field may be restored by turning the analyser through the same number of degrees through which the plane of vibration of the polarized light was rotated by the optically active substance. Thus, if the analyser must be rotated 20°, it shows that the optically active substance rotated the ray of polarized light to that extent.

The rotatory power of an optically active substance is a physical constant (just as is the solubility) and may be used for the identification and determination of the substance. To facilitate comparison, the rotatory power is observed under specific conditions and is then termed the *specific rotatory power* of that substance. (See United States Pharmacopoeia).

Determinations of rotatory power are of great value in proving the identity or purity of certain alkaloids, certain volatile oils (see Oil of Lemon, United States Pharmacopoeia), and in the determination of the various sugars. Volatile oils require no preliminary treatment other than that made necessary by foreign suspended matter or coloring matter. But sugars are brought into aqueous solution of certain concentration.

DETERMINATION OF SUCROSE IN LIGHT COLORED SUGARS AND MOLASSES.

Process.—Weigh out 16.192 Gm. of the sample very accurately; place in a 100 cc. cylinder; dissolve in pure distilled water; and dilute up to the 100 cc. mark. Having previously carefully cleaned the 200 mm. tube of the polariscope, rinse it out with a few cc. of the saccharine solution. Then fill the tube completely, being careful to avoid the presence of air bubles. Having placed the polariscope in a darkened room, furnished it with a sodium light, and set it to zero, insert the tube filled with the sugary solution, and note the appearance of the field. The left half will appear bright, while the right half will be darkened. Turn the analyser in the direction of the darkened half until the field appears to be evenly illuminated, and then take the reading. The temperature at which the polarization is made must also be carefully noted.

Pour the contents of the tube back into the cylinder. Then place 50 cc. in a flask graduated to hold 100 cc.; add 5 cc. of strong hydrochloric acid; and warm in a water-bath at a temperature of 68°C. for fifteen minutes. Remove the flask from the water-bath; cool to the temperature at which the first polarization was made; and dilute to the 100 cc. mark with pure distilled water at the same temperature. Again fill the 200 mm. tube with the solution, and polarize as before, noting carefully whether the analyser must be turned to the left or to the right in order to make the field appear homogeneous. Remember always to turn the analyser toward the darkened half of the field. Then, if the polarization has been to the left, mark the reading "—"; if to the right, mark it "+." Double the reading obtained, on account of the dilution.*

Calculation.—It has been determined by experiment that a pure sugar solution which will indicate a rotation of +100°, will, after inversion, indicate a rotation of -42.4°, if observed at 0°C. Thus the total change due to inversion is 142.4°. If, however, the temperature be increased, the rotation after inversion will be .5° less for each degree Centigrade of increase in temperature. Thus, at 20°C., the total change would be $142.4 - \frac{1}{2}t$ or 132.4.

(1.) If a total change of $142.4 - \frac{1}{2}t$ indicates a rotation, due to sucrose, of 100° to the right before inversion, then whatever may be the total change in the sample under examination, this total change will indicate a rotation, due to sucrose, in the ratio of $142.4 - \frac{1}{2}t : 100$. Accordingly, to find degrees due to sucrose:

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*For very accurate work correction must be made for change in specific rotatory power, due to dilution.

Let D = Total change produced by inversion.
t = Temperature (Centigrade scale).
R = Degrees due to sucrose.
Then, (142.4—½t) : 100 :: D : R or

$$R = \frac{100\ D}{142.4 - \frac{1}{2}t}$$

Example.—If the rotation before inversion is +20° 30′, and after inversion is –6° 15′, and the temperature is 20°C., find the degrees due to sucrose.

D = 26° 45′ or 26.75°
t = 20°.

$$R = \frac{100 \times 26.75}{142.4 - \frac{20}{2}} = \frac{2675.}{132.4} = 20.203.$$

Thus 20.203° of the 20° 30′ are due to sucrose.

(2.) If a one decimeter tube be employed, a rotation due to sucrose and equal to the specific rotatory power of that substance would indicate 100 Gm of sucrose. If a two decimeter tube is employed, a rotation equal to twice the specific rotatory power would indicate 100 Gm. Then, whatever may be the rotation due to sucrose in the sample under examination, this rotation indicates a number of grammes of sucrose in the ratio of (L × 66.5) : 100, where L is the length in decimeters of the tube employed, and 66.5 is the specific rotatory power of sucrose. Accordingly, to find Gm. of sucrose in the amount of sample operated on:

Let G = Gm. of sucrose in amount operated on.
Then, (L × 66.5) : 1co :: R : G or

$$G = \frac{100\ R}{L \times 66.5}$$

Example (*continued*).—In example under (1.), the degrees due to sucrose are found to be 20.203. Find Gm. of sucrose indicated, if the 200 mm. tube has been used in the polarization.

$$G = \frac{100 \times 20.203}{2 \times 66.5} = \frac{2020.3}{133} = 15.19$$

Thus there are 15.19 Gm of sucrose in the amount of sample weighed out.

(3.) To find per cent of sucrose:
Amount weighed out (normal weight) : G :: 100 : x. x = per cent of sucrose.

Example (*concluded.*)—16.192 : 15.19 :: 100 : 93.81. Thus, the per cent of sucrose in the sample is 93.81.

DETERMINATION OF SUCROSE IN DARK COLORED SUGARS AND MOLASSES.

It is necessary to decolorize such substances before they can be polarized. This is usually accomplished by means of precipitated aluminum hydroxide, lead subacetate solution, or blood charcoal. The simple addition of "alumina cream" or filtration through blood charcoal is sufficient to decolorize only moderately colored solutions, while for the very dark ones, lead subacetate solution is necessary.

Preparation of Alumina Cream.—Make 100 cc. of a saturated solution of alum. To 75 cc. of this solution add ammonium hydroxide until the latter is in excess. Then add enough of the remaining 25 cc. of alum solution to give the mixture a faintly acid reaction.

Preparation of Lead Subacetate Solution.—(See United States Pharmacopoeia, page 237).

Process.—Weigh out the "normal weight" for the Laurent polariscope, 16.192 Gm., and dissolve in enough water to make 60 cc. of solution. Then add from 5 to 10 cc. of alumina cream, or from 5 to 10 cc. of lead subacetate solution and an equal amount of alumina cream, depending upon the darkness of the solution to be decolored. Shake well; add enough of sodium sulphate solution to precipitate out the excess of lead; and then dilute to the 100 cc. mark with distilled water. Filter through perfectly dry paper; reject the first few cubic centimeters; and collect the remainder in a dry beaker. If the solution is still too darkly colored to admit of polarization, filter through a layer of perfectly dry blood-charcoal, again rejecting the first portion of the filtrate. Render the filtrate acid with acetic acid in order to break up the compound formed by the laevulose and the lead. Then proceed to polarize, invert, etc., as directed under Process for Light Colored Sugars and Molasses. The calculation is also the same as for the preceding process, except in case much precipitate occurs, when a correction must be made for change in volume.

TABLE OF ATOMIC WEIGHTS.

[*According to L. Meyer and K. Seubert.*]

Symbol.	Atomic Weight.	Symbol.	Atomic Weight.	Symbol.	Atomic Weight.
Al	27·04	Co	58·6	N	14·01
Sb	119·6	Cu	63·18	O	15·96
As	74·9	Au	196·7	P	30·96
Ba	136·9	H (Standard)	1·0	Pt	194·3
Bi	208·9	I	126·53	K	39·03
B	10·9	Fe	55·88	Si	28.3
Br	79·76	Pb	206·4	Ag	107.66
Ca	39·91	Li	7·01	Na	23·0
C	11·97	Mg	24·3	Sr	87·3
Ce	139·9	Mn	54·8	S	31·98
Cl	35·37	Hg	199·8	Sn	118·8
Cr	52·0	Mo	95·9	Zn	65·1

TABLE OF ALKALOIDAL FACTORS AND SOLUBILITIES.

	Decinorm. Factor.	SOLUBILITY IN PARTS OF SOLVENT.				
		Water.	Alcohol.	Ether.	Chloroform.	Petrol. Ether.
Atropine	.0289	130	3	16	4	——
Atropine Sulphate.	——	.4	6.2	2270	694	——
Berberine	——	500	spar. sol.	insol.	slightly	insol.
Caffeine	Can't be titrated	80	33	555	7	——
Caffeine Sulphate.	——	decomp.	——	——	caff. dissol	——
Cinchonine	.02934	3760	116	526	163	——
Cinchonidine	.02934	1680	17	188	freely	——
Cocaine	.0303	slightly	freely	freely	freely	freely
Codeine	.02984	80	3	30	2	——
Coniine	.0128	90	freely	freely	freely	freely
Emetine	.0254	spar. sol.	freely	freely	freely	——
Hydrastine	Feebly basic	insol.	freely	freely	freely	——
Hyoscine	.0289	spar. sol	freely	freely	freely	——
Hyoscyamine	.0289	spar. sol.	freely	freely	freely	——
Morphine	.0303	4350	300	4000	——	——
Narcotine	——	spar. sol	freely	freely	——	——
Physostigmine	.0275	spar. sol.	freely	freely	freely	——
Pilocarpine	.0208	spar. sol.	freely	freely	——	——
Quinine, crystalline	.0377	1670	6	23	5	sol.
Quinidine	.0324	2000	26	80	freely	spar. sol.
Strychnine	.0334	6700	110	insol.	7	——
Veratrine	——	spar. sol.	3	6	2	——
Aconite Bases	.0647					
Belladonna Bases	.0289					
Colchicum Bases	.0399					
Gelsemium Bases	.0408					

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